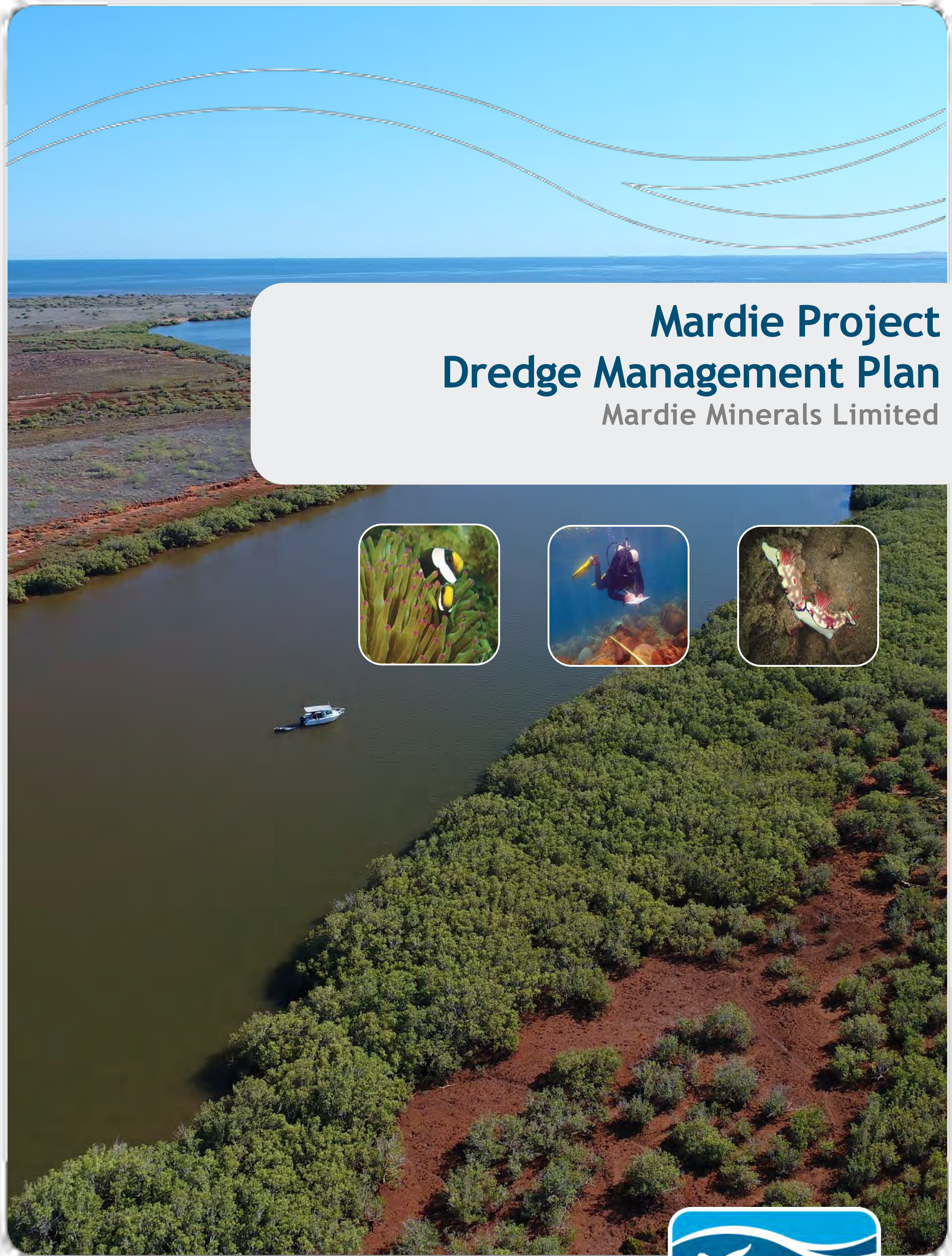

Mardie Project
Dredge Management Plan
Mardie Minerals Limited

CLIENT: Mardie Minerals Pty Ltd
STATUS: Rev 2B **REPORT No:** R190043
ISSUE DATE: 24rd June 2021

O2 MARINE

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Version Register

Version	Status	Author	Reviewer	Change from Previous Version	Authorised for Release (signed and dated)	
0	Final	J.Abbott C Del Deo	C.Lane	Update Monitoring Program	C. Lane	20/04/2020
1	Final	J.Abbott C Del Deo	C.Lane	Update Monitoring Program	C. Lane	10/11/2020
2	Final	J Abbot T Wiegele	C Lane	Incorporate DWER review	C. Lane	16/06/2021

Transmission Register

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Acronyms and Abbreviations

Acronyms/Abbreviation	Description
BCH	Benthic Community Habitats
DAWE	Department of Agriculture Water and Environment (Cth)
DoF	Department of Fisheries
DMP	Dredge Management Plan
DWER	Department of Water and Environment Regulation
EPA	Environmental Protection Authority
EPO	Environmental Protection Outcomes
ESD	Environmental Scoping Document
ha	Hectares
ktpa	Thousand tons per annum
m^3	Cubic meters
mAHD	Meters Australian Height Datum
MEQ	Marine Environmental Quality
MTs	Management Targets
Mtpa	Million tons per annum
MWQMP	Marine Water Quality Monitoring Program
PASS	Potential Acid Sulfate Soils
PER	Public Environmental Review
The Proponent	Mardie Minerals Pty Ltd
The Proposal	The Mardie Project
SOP	Sulphate of Potash
SOPEP	Shipboard Oil Pollution Emergency Plan
SOW	Scope of Works
TMF	Tiered Management Framework
TTS	Temporary Threshold Shift
UAV	Unmanned Arial Vehicle
ZoHI	Zone of High Impact
ZoI	Zone of Influence
ZoMI	Zone of Moderate Impact

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1. Introduction

1.1. Short Summary of the Proposal

Table 1. Short Summary of the Proposal

Proposal Title	Mardie Project
Proponent Name	Mardie Minerals Pty Ltd
Short Description	Mardie Minerals Pty Ltd is seeking to develop a greenfields high quality salt and sulphate of potash (SOP) project and associated export facility at Mardie, approximately 80 km southwest of Karratha, in the Pilbara region of WA. The proposal will utilise seawater to produce a high purity salt product, SOP and other products derived from sea water. The proposal includes the development of a seawater intake, concentrator and crystalliser ponds, processing facilities and stockpile areas, bitterns disposal pipeline and diffuser, trestle jetty export facility, transhipment channel, drainage channels, access / haul roads, desalination (reverse osmosis) plant, borrow pits, pipelines, and associated infrastructure (power supply, communications equipment, offices, workshops, accommodation village, laydown areas, sewage treatment plant, landfill facility, etc.).

1.2. Proponent

The proponent for the proposal is Mardie Minerals Pty Ltd which is a wholly owned subsidiary of BCI Minerals Pty Ltd. Proponent details are provided in **Table 2**.

Table 2. Proponent Details

Company Name:	Mardie Minerals Pty Ltd
Australian Business Number (ABN):	50 152 574 457
Address:	1 Altona Street West Perth
Key Contact (Role):	Neil Dixon (Manager Environment & Approvals)
Key Contact Details:	Email: Neil.Dixon@bciminerals.com.au Phone: +61 8 6311 3400

1.3. Project Description

Mardie Minerals Pty Ltd (Mardie Minerals) seeks to develop the Mardie Project (the proposal), a greenfields high-quality salt project in the Pilbara region of Western Australia (**Figure 1**). Mardie Minerals is a wholly-owned subsidiary of BCI Minerals Limited.

Figure 1. Project Location

The proposal is a solar salt project that utilises seawater and evaporation to produce raw salts as a feedstock for dedicated processing facilities that will produce a high purity salt, industrial grade fertiliser products, and other commercial by-products. Production rates of up to 4.4 Million tonnes per annum (Mtpa) of salt (NaCl) and 110 kilotonnes per annum (ktpa) of Sulphate of Potash (SoP) are being targeted, sourced from a 150 Gigalitre per annum (GLpa) seawater intake. To meet this production, the following infrastructure will be developed (Figure 2):

- Seawater intake, pump station and pipeline;
- Concentrator ponds;
- Drainage channels;
- Crystalliser ponds;
- Trestle jetty and transhipment berth/channel;
- Bitterns disposal pipeline and diffuser;
- Processing facilities and stockpiles;
- Administration buildings;
- Accommodation village,
- Access / haul roads;

- Desalination plant for freshwater production, with brine discharged to the evaporation ponds; and
- Associated infrastructure such as power supply, communications, workshop, laydown, landfill facility, sewage treatment plant, etc.

Seawater for the process will be pumped from a large tidal creek into the concentrator ponds. All pumps will be screened and operated accordingly to minimise entrapment of marine fauna and any reductions in water levels in the tidal creek.

Concentrator and crystalliser ponds will be developed behind low permeability walls engineered from local clays and soils and rock armoured to protect against erosion. The height of the walls varies across the project and is matched to the flood risk for the area.

Potable water will be required for the production plants and the village. The water supply will be sourced from desalination plants which will provide the water required to support the Project. The high salinity output from the plants will be directed to a concentrator pond with the corresponding salinity.

The production process will produce a high-salinity bittern that, prior to its discharge through a diffuser at the far end of the trestle jetty, will be diluted with seawater to bring its salinity closer to that of the receiving environment.

Access to the project from North West Coastal Highway will be based on an existing road alignment that services the Mardie Station homestead.

1.3.1. Marine Infrastructure and Activities

Salt and SOP produced at the project will be exported offshore through the specially constructed port operations (Figure 3).

A 4 km long trestle jetty will be constructed to convey salt and SOP to the transhipment berth pocket for loading onto the transhipping barge. The jetty will not impede coastal water or sediment movement, thus ensuring coastal processes are maintained.

Dredging of up to 800,000 m^3 (the current estimate is 650,000 m^3) will be required to ensure sufficient depth for the transhipper berth pocket at the end of the trestle jetty, as well as along a 4 km long channel out to deeper water. The average depth of dredging is approximately 1 m below the current sea floor. The dredge spoil is inert and will be transported to shore for use within the development.

1.4. Purpose

The purpose of this Dredge Management Plan (DMP) is to ensure compliance with Ministerial Statement (pending). Ministerial Statement (pending) includes project specific Environmental Protection Outcomes (EPO)s, and the Proponent has proposed Management Targets (MTs) and specific management and monitoring actions to ensure that these EPOs are achieved.

Figure 2: Indicative location of ponds and infrastructure

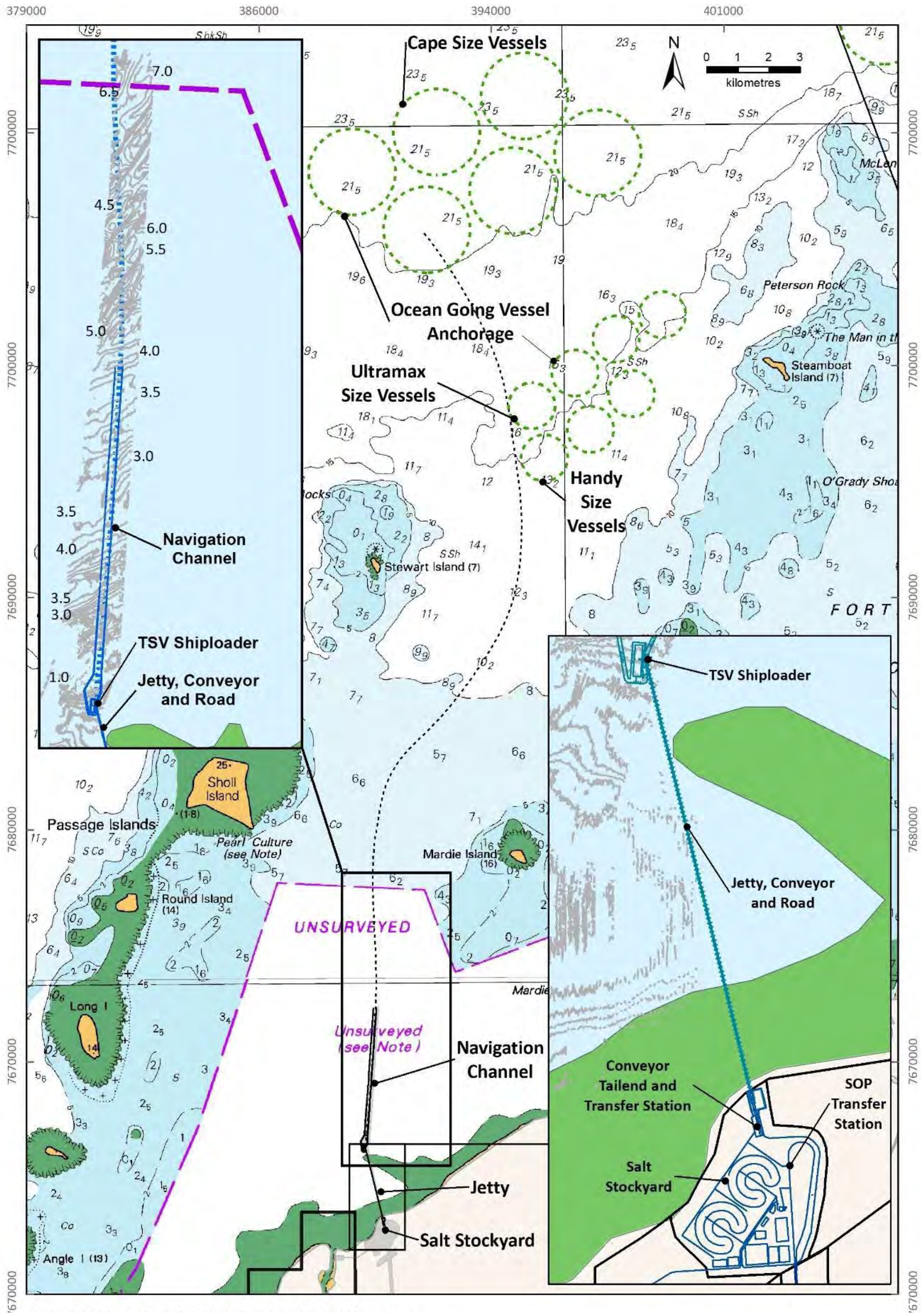

Figure 3: Mardie project offshore export operations

2. Existing Environment

This section describes the existing environment at the site of the Project and surrounding waters, as it relates to the purpose and scope of this plan. The description is based on information derived from historical sources and from investigations conducted as part of the environmental impact assessment process for the Mardie Project.

2.1. Climate

The Project is located in the southern Pilbara region, which has a tropical monsoon climate with distinct wet and dry seasons. The Pilbara coast is the most cyclone prone area along the Australian coastline, with the cyclone season running from mid-December to April and peaking in February - March (Sudmeyer, 2016).

2.1.1. Wind

The dry season extends from May to October, and is characterised by warm to hot temperatures, easterly to south-easterly winds from the continental landmass, clear and stable conditions as the subtropical high-pressure ridge migrates over this area. In the afternoons, the winds generally shift to north-westerly, particularly later in the dry season, associated with the onset of the land sea breeze as the temperature difference between the continent and the ocean increases throughout the day. In the wet season the wind climate is dominated by westerly and north-westerly winds. Wind rose plots for the Dry Season months (May to October) and Wet Season months (November to April) are presented in **Figure 4** based on analysis of the measured wind records from Mardie Airport over the period 2011 - 2018.

Maximum daily temperatures at Mardie average 33.9 °C throughout the year, peaking at 38.0 °C in January and falling to 27.7 °C in July. The Pilbara is influenced by northern rainfall systems of tropical origin. These systems are responsible for heavy falls during the summer months, while the southern low-pressure systems sometimes bring limited winter rains. The annual average rainfall is only 128 mm, and the mean monthly rainfall has a bimodal distribution, peaking in January to March and also May to June, with very little rainfall from July to December. Daily rainfall can reach over 300 mm during extreme events that may occur one to two times per decade. Evaporation rates in the region are high, estimated to exceed by ten times the annual rainfall.

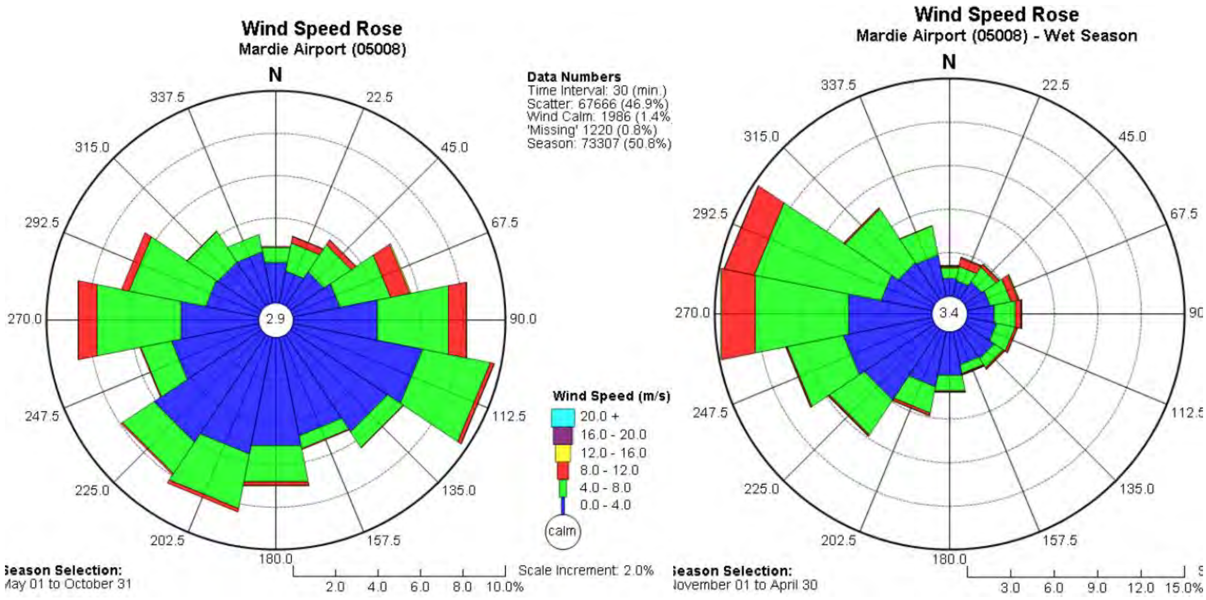

Figure 4. Wind Rose plots for Dry Season (left) and Wet Season Months (right) based data from Mardie airport.

2.1.2. Temperature and Rainfall

Maximum daily temperatures at Mardie average 33.9 °C throughout the year, peaking at 38.0 °C in January and falling to 27.7 °C in July (**Figure 5**). The Pilbara is influenced by northern rainfall systems of tropical origin. These systems are responsible for heavy falls during the summer months, while the southern low-pressure systems sometimes bring limited winter rains. The annual average rainfall is only 128 mm, and the mean monthly rainfall has a bimodal distribution, peaking in January to March and also May to June, with very little rainfall from July to December. Daily rainfall can reach over 300 mm during extreme events that may occur one to two times per decade. Evaporation rates in the region are high, estimated to exceed by ten times the annual rainfall.

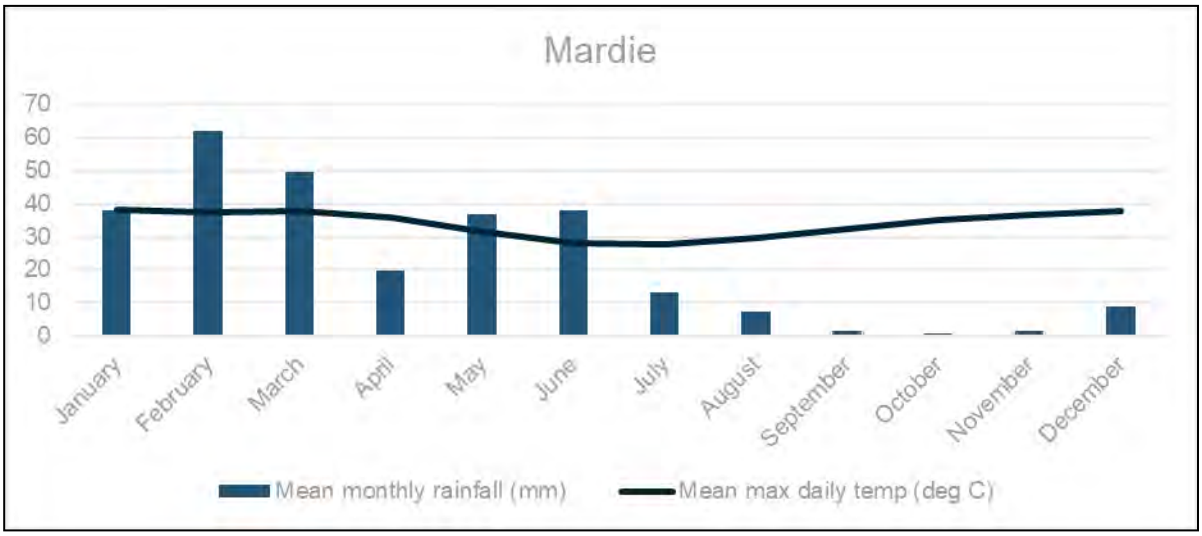

Figure 5. Climate Statistics for Mardie (BOM)

2.1.3. Tropical Cyclones and Storm Surge

The Australian cyclone season extends from November through to April with an average of 10 cyclones per year, although not all make landfall. Tropical cyclone winds can generate extreme coastal water levels through storm surge and these systems are frequently associated with heavy rainfall that can cause significant flooding. The Pilbara region of Western Australia has a high exposure to tropical cyclone events, with a typical cyclone track recurving and making landfall on the coastline between Broome and Exmouth. The season typically runs from mid-December to April, peaking in February and March. The Karratha to Onslow coastline is the most-cyclone prone section of the Australian coast, typically experiencing one landfalling event every two years.

Historical events of significance impacting between Karratha and Onslow include: Trixie 1975, Chloe 1984, Orson 1989, Olivia 1996, John 1999, Monty 2004, Clare 2006 and Glenda 2006 (**Figure 6**). In late March 2019 the passage of TC Veronica tracked west over the region from offshore of Karratha losing intensity as it continued west offshore of Mardie as a tropical low system.

The northwestern coastline of Western Australia is highly vulnerable to the occurrence of storm surge. This is due to the frequency of tropical cyclones, the wide continental shelf and relatively shallow ocean floor over the North West Shelf, as well as the low-lying nature of much of the coastline. In addition, tropical cyclone events are strongly associated with flooding due to widespread heavy rainfall.

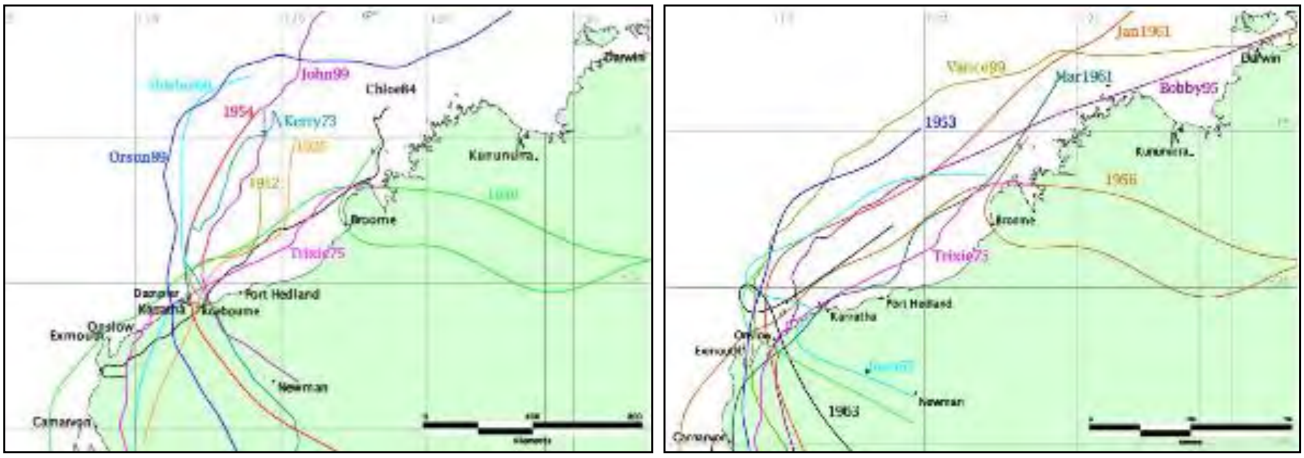

Figure 6. Tracks of notable cyclones impacting Karratha (left) and Onslow (right)

2.2. Coastal

2.2.1. Bathymetry

The offshore components of the Mardie Project (jetty and dredge channel) are situated in an area shown as unsurveyed on marine charts (Figure 3). Mardie Minerals has conducted several detailed bathymetric studies over the previously unsurveyed area, as well as surrounding areas to verify chart soundings (e.g. Surrich Hydrographics 2019). The jetty will extend from the shoreline at approximately +1.5 mLAT, out to an area at 0 mLAT (**Figure 7**). The berth pocket at the end of the jetty has a design depth of -6.7 mLAT and the dredge channel -3.9 mLAT.

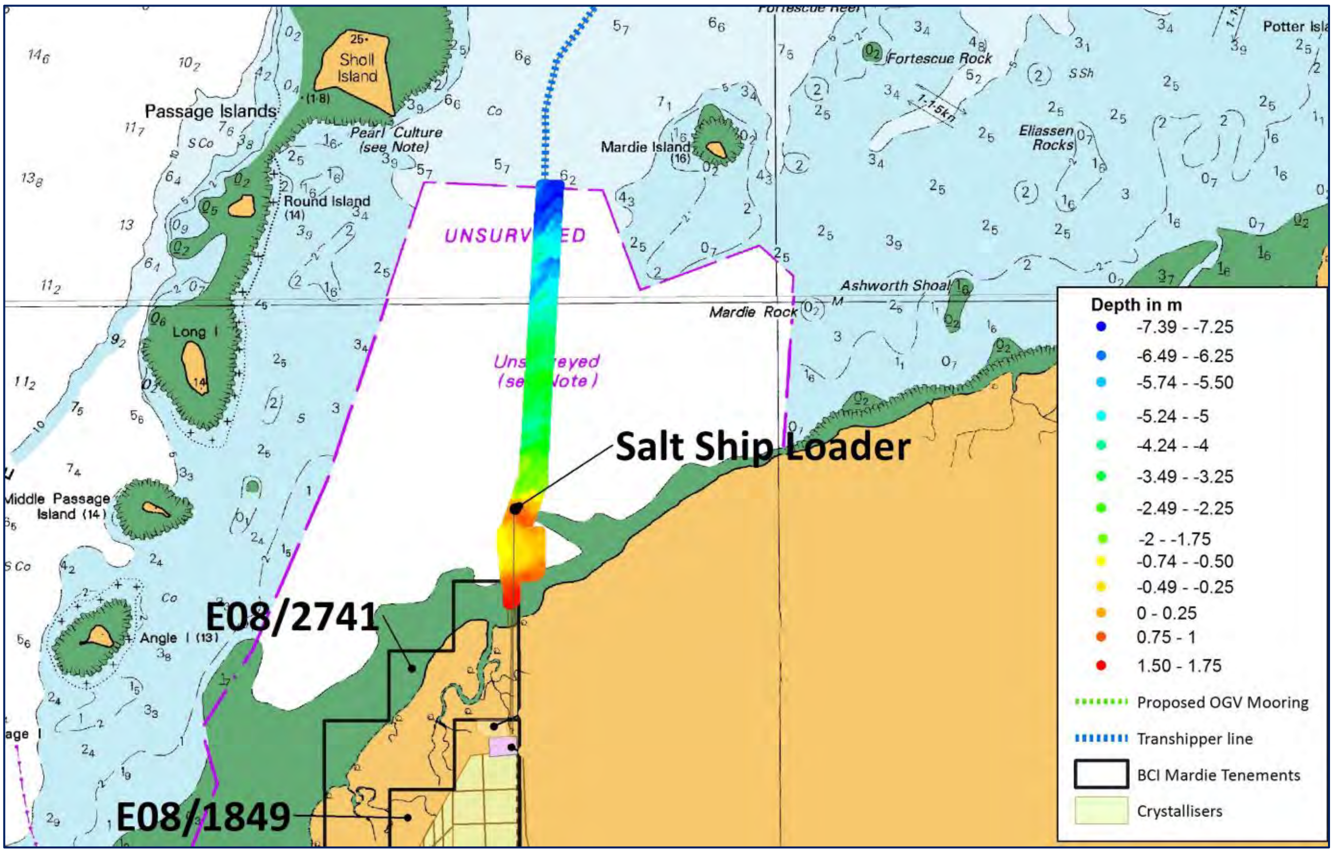

Figure 7. Bathymetry of jetty and dredge channel

2.2.2. Tides

The Mardie project location experiences a semi-diurnal tide (two highs and two lows a day) and the tidal planes have been defined by the National Tide Centre (NTC) based on field measurements completed for the project in late 2018 (O2 Marine 2020). The Mardi Gauge (MardiLAT18) datum definition completed by the NTC shows that the offset between LAT and MSL is 2.75 m, and the total tidal range is 5.185 m. The mean tide range is 3.6 m in springs and 1 m in neaps.

Measured data from an inshore Aquadopp in November 2018 is shown in **Figure 8** illustrating the water level time series through the spring and neap cycles. It is noted that the instrument could not measure tide levels below -2 m MSL.

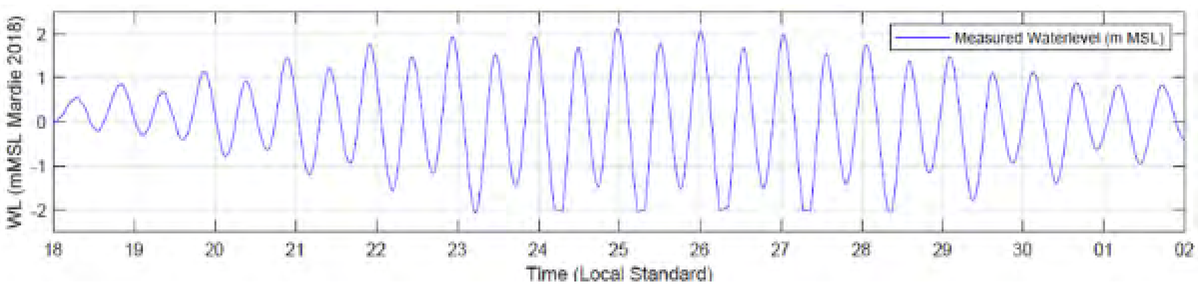

Figure 8. Measured water level data from inshore Aquadopp location November 2018

2.2.3. Waves

The northwest shelf of Western Australia experiences waves generated from three primary sources: Indian Ocean swell, locally generated wind-waves and tropical cyclone waves. Along the shoreline the ambient (non-cyclonic) wave climate is generally mild. In dry season months low amplitude swell originating in the Indian Ocean propagates to the site and occurs in conjunction with locally generated sea waves of short period (<5s). In the wet season the wave climate is locally generated sea waves from the south to southwest. In general, the significant wave height is dominated by locally generated sea conditions within the range of 0.5m to 1m at short wave periods (Tp< 5 s). Measured data from an ADCP instrument deployed approximately 15km offshore for the project has been analysed to characterise the wave conditions in the wet and dry seasons as shown in **Figure 9**.

Whilst the non-cyclonic ambient wave conditions are generally mild, in contrast the strong winds in a tropical cyclone can generate extreme wave conditions. It is noted that the offshore island features would provide some natural protection form extreme wave conditions depending on the direction of propagation. Extreme cyclonic waves contribute to the total water level through wave run-up which is the maximum vertical extent of wave uprush on a beach and is comprised both wave set-up and swash. The impact of cyclonic waves on the study site is dependent on the prevailing water level conditions and direction of cyclone approach. If coincident with a spring tide and storm surge, waves could propagate beyond the typical position of the beach and induce erosion of the shoreline as well as sediment transport.

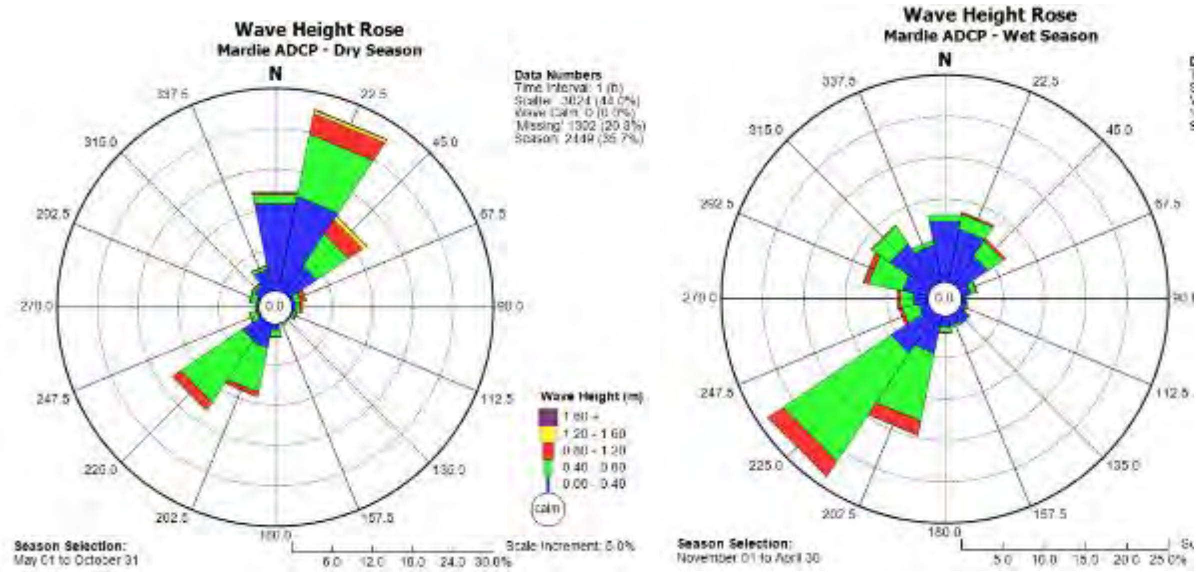

Figure 9. Wave conditions offshore of the Mardie Proposal location for Dry Season months (left) and Wet Season Months (right) based on measured data April 2018 – January 2019

2.3. Substrate and BCH

The project area is located in shallow (<6 m) nearshore waters located approximately 5 km offshore, north from the Mardie Coastline and southwest from the Fortescue River-mouth. The seafloor in this area is generally comprised of unconsolidated silt, sand and gravel.

O2 Marine (2019b) identified the nearshore subtidal zone to support benthic primary producers such as sparse patches of macroalgae, seagrass and corals (**Figure 10**). The majority of the subtidal benthic substrata is abiotic, characterised by bare sand and silt with limited limestone pavement and ridges. Many of the limestone ridges also occur around the offshore islands and support assemblages of macroalgae, corals and sponges. Whilst the extensive subsea plains of sand/silt are often bare of any sessile mega-benthic taxa (such as coral and macroalgae), these habitats do support smaller infaunal species and surface-dwelling echinoderms and filter feeders such as hydroids.

Table 3: BCH classes recorded at Mardie (O2 Marine 2019b)

BCH Class	Description	Example Image
Bare / bioturbated sand	**Bare Silt / Sand** Typically comprises of silt or sand with no or occasional very sparse macroalgae. Silt areas often comprised of bioturbation (burrows formed by living organisms). Sand areas often contain traces of shell grit. This habitat comprises 89% of the mapped subtidal BCH and is also widely dispersed across the region.	
	Sand / Sparse (<5%) Macroalgae Fine silt/sand and bioturbated bedform with a very patchy distribution of macroalgae and invertebrates. Macroalgae (*Phaeophyta*) was the dominant cover, but was very sparse, generally comprising <1% of the overall cover. Class was differentiated from the other macroalgal classes due to the very sparse nature of the cover and the much finer grained, and often bioturbated sediments. This habitat comprises 1% of the mapped subtidal BCH. It was also observed on the eastern fringing waters of Round Island, whilst the largest contiguous area was observed closer to the mainland in the shallow waters between Angle Island and the mainland.	
Filter feeder/ macroalgae / seagrass	**Sand / Sparse (<5%) Filter Feeders** Sparse filter feeder habitat occurs where the relief is flat and is associated with fine to coarse sands. Although only present in sparse densities (<5% cover), hydroids are most common where there is no bedform, whilst sponges occur where there is some bioturbation. This habitat comprises 2% of the mapped subtidal BCH and is widely dispersed throughout the region.	

BCH Class	Description	Example Image
Filter feeder/ macroalgae / seagrass	**Low (5-10%) Cover Macroalgae / Filter Feeders** Flat to low relief constituting either fine to coarse sands, including shell grit on occasions. Macroalgae, hydrozoan and sponge species are equally dispersed throughout this habitat although benthic cover is low (3-10%). Occasional very sparse (<1%) cover of *Halophila* sp. seagrass was also observed at some locations. This habitat comprises 6% of the mapped subtidal BCH and follows a patchy distribution throughout the region. This habitat was also observed in small patches fringing the shallow waters of Long Island, Mardie Island and close to the mainland.	
Coral/ macroalgae	**Low (5-10%) Cover Coral** Flat to low relief rock and rubble with coarse sand. Low (3-10%) cover of soft and hard corals, including *Faviidae, Dendrophyllidae, Mussidae and Octocroals*. Sparse macroalgae was also present. This habitat comprises 1% of the mapped subtidal BCH. This habitat was also found fringing Mardie Island and in small isolated patches between Angle Island and the mainland. It was generally recorded in waters between 1-3 m depth.	
	Moderate (10-25%) Cover Coral / Macroalgae Low to moderate relief rock and rubble/coarse sand. Low to moderate cover (3 – 25%) of soft and hard corals with macroalgae. Corals largely consisted of *Faviidae, Poritidae, and Octocorals,* while *Phaeophyceae* dominated the macroalgae communities. This habitat class comprises only 1% of the mapped subtidal BCH. However, it was also recorded in larger areas in fringing shallow waters south of Mardie Island and adjacent to the mainland coast.	

BCH Class	Description	Example Image
Coral/ macroalgae	**Dense (>25%) Cover Macroalgae / Coral / Filter Feeders** This habitat class occurs on low relief substrate with fine to coarse sands and areas of exposed limestone reef. Dense assemblages (>75%) of macroalgae and hydrozoan species predominately in waters at depths of 2.2-4.0 m. This habitat also supported sparse juvenile corals (*Faviidae, Dendrophyllidae, Mussidae)* with occasional larger coral (*Poritidae*) bommies (1–2 m diameter). This habitat class comprised <1% of the mapped subtidal BCH. It was also identified in the waters fringing the eastern outer edge of Long Island, Round Island and Sholl Island.	
	Dense (>25%) Cover Coral Dominated Low relief limestone reef and rubble substrate which supports high coral cover (25-75%) of diverse coral species, including *Faviidae, Dendrophyllidae, Mussidae, Portitidae*, and *Octocoral* species. This habitat class was only recorded at one location and, as such, comprises <1% of the mapped subtidal BCH. However, it was also recorded in a much larger area fringing the northern edge of Mardie Island.	

A total of 79 ha of benthic community habitat (BCH) will be cleared (i.e. directly impacted) by dredging and a further 202 ha is predicted to recover from the dredging operations. This BCH includes 35 ha (cleared) and 133 ha (recoverable) of filter feeder / microalgae / seagrass habitat and 10 ha (cleared) and 103 ha (recoverable) of coral / macroalgae habitat[1].

A baseline sediment assessment of the Mardie Project identified that of the Contaminants of Potential Concern (CoPC) analysed, only arsenic and nickel (95% UCL of mean) concentrations exceeded the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018). However, some concentrations of metals and nutrients were naturally higher than recorded for marine sediment programs in other areas of the Pilbara (O2 Marine, 2019a).

All sediment samples collected within the dredge footprint were non-PASS (O2 Marine, 2019a) and baseline sediment results indicate that dredge sediments are suitable for onshore disposal. As per the

[1] Although seagrass was identified in the impact area, it was present only in extremely low densities (i.e. almost undetectable), making coral the primary benthic community of concern with respect to dredging impacts. Seagrass, macro algae and filter feeder communities will still be monitored, however, these habitats are given less weight when identifying impacts from the proposed dredge activities and will be used to validate predicted impact to BCH.

recommendations of O2 Marine 2019a (Appendix 5-1 the Sediment Quality Assessment Report), a revised site-specific EQC has been developed for the Mardie Project area (**Table 18** in O2 Marine 2019a).

Sediments will be monitored throughout the dredging and post-dredging operations for the presence of ASS and CoPC (refer to Section 6.2 for further information). In the event that testing identifies higher risk PASS material is encountered during dredging, then this material will be well mixed with material containing predominantly calcareous materials to ensure that the natural ANC of the marine sediments is sufficient to buffer overall acid generating processes.

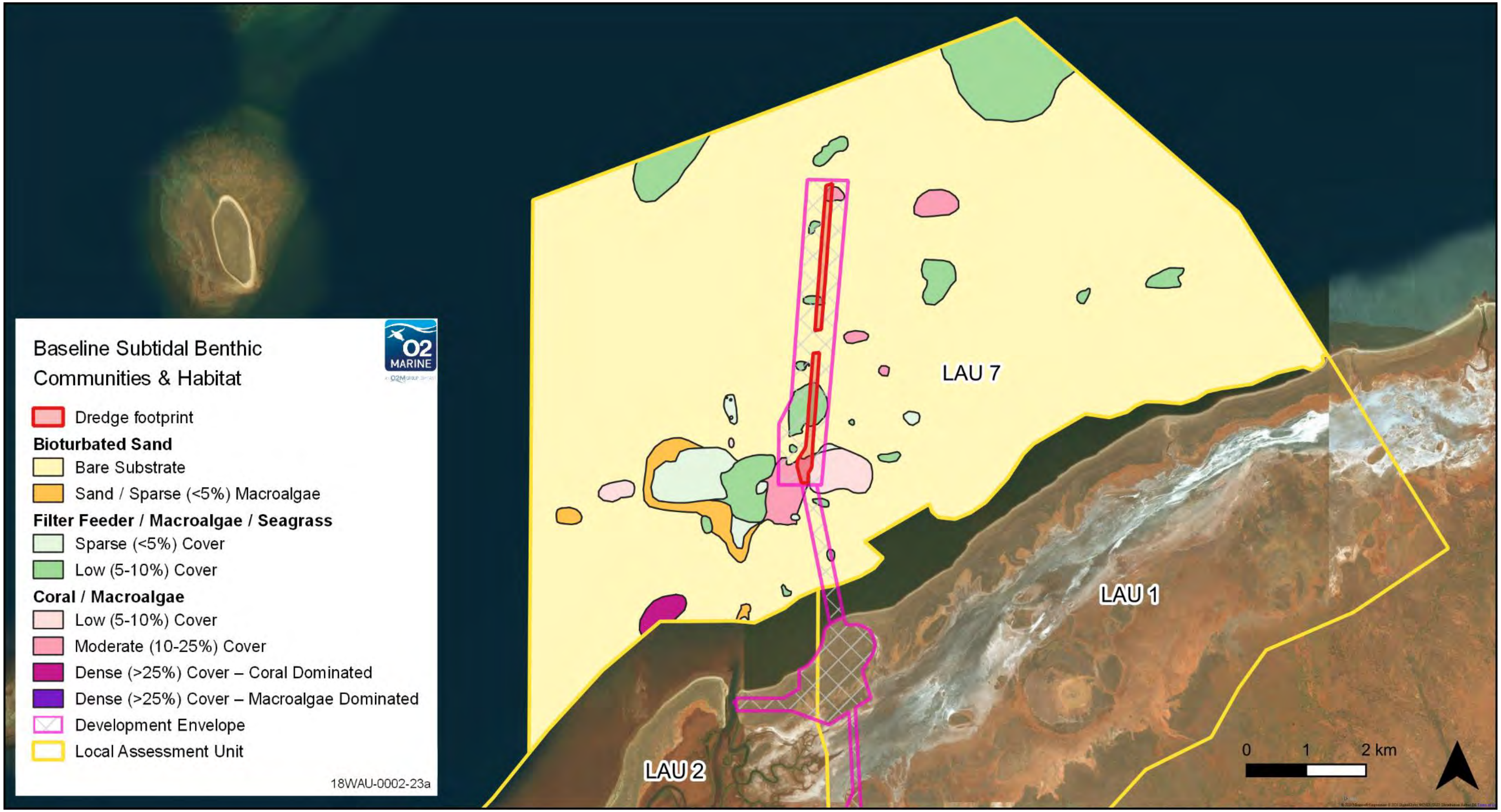

Figure 10. Project Subtidal Benthic Community Habitats (O2 Marine 2019b).

2.4. Marine Water Quality

Nearshore waters typical of this region are characterised by variable turbidity and high sedimentation rates, with associated highly variable light regimes and seawater temperatures. Offshore waters exhibit fewer extremes in the water quality, but still display occasional high levels of sedimentation and turbidity, low light and variable seawater temperatures (Pearce *et al*, 2003).

Light, turbidity, seawater temperature and sedimentation rates are typically weather dependent and show a strong seasonal transition from the dry to the wet seasons. Large daily tidal ranges (>5 m), strong winds (gusts >50 km/h) and increased wave activity (such as associated with cyclonic activity) can impact background conditions resulting in increased turbidity (in the form of increase suspended sediment concentration (SSC) due to coastal runoff and wind/wave driven sediment resuspension. In summary, waters in the vicinity of the project area are subject to naturally elevated levels of turbidity and a reduced light climate heavily influenced by discrete weather events (Pearce *et al*, 2003).

O2 Marine (2020a) identified the following from marine water quality baseline studies conducted at the Mardie Project study area.

> Salinity levels recorded a median value of 37.5 ppt, and appeared to be indicative of a sheltered bay, which was thought to be due to the influence of the Passage Islands which act as a natural barrier and appear to restrict mixing with lower salinity oceanic waters;

> Turbidity and SSC were found to be higher at the inshore monitoring location than at the offshore location, which is consistent with other Pilbara water quality investigations (Jones *et al*. 2019; MScience 2009; Pearce 2003);

> Derived Daily light Integral (DLI) around the coastal islands was highest during wet season and lowest during the dry season and correlated with seasonal change in solar elevation angle, which is a primary factor influencing the amount of available benthic light in these areas. Conversely, DLI was low year-round at the inshore location (i.e., dredging area). Factors influencing benthic light levels are different between the islands and dredging area. However, the lowest light levels in both areas corresponded closely with high SSC and turbidity levels, associated with the passing of several Tropical Cyclones and low-pressure systems over the sampling period;

> Importantly, the recently published WAMSI (Jones *et al*. 2019) SSC and DLI thresholds for *possible* and *probable* effects on coral were found to be poorly suited as criteria for monitoring dredging effects in the Mardie Project area. Frequent natural exceedances of SSC and DLI thresholds indicates that these thresholds are unsuitable for use as water quality and dredge activity monitoring criteria in the Mardie Project area. It is noted that Jones *et al.* (2019) recognises these potential limitations of the thresholds and advises that WAMSI is in the process of developing thresholds for turbid water coral communities. Once these new turbid water thresholds are available, they should be evaluated against the baseline data collected in this program and as part of the pre-dredging baseline to determine suitability for use in dredge monitoring;

> Laboratory analysis of marine water samples showed no evidence of contamination and the current allocation of maximum and high levels of ecological protection are appropriate for the marine waters of the Mardie Project area.

2.5. Marine Fauna

O2 Marine (2020d) undertook an assessment of the likelihood of occurrence for threatened marine mammal species identified through the desktop review, based on the list of species provided in the ESD (Preston, 2018).

Listed threatened marine mammals with high potential to occur or are known to occur off the Mardie coast (on occasion) include:

Marine Mammals:
- Humpback whale (*Megaptera novaeangliae*);
- Dugong (*Dugong dugong*); and
- Australian humpback dolphin (*Sousa sahulensis*).

Marine Turtles:
- Loggerhead turtle (*Caretta caretta);*
- Green turtle (*Chelonia mydas*); and
- Flatback turtle (*Eretmochelys imbricate*)

Elasmobranch:
- Green sawfish (*Pristis zijsron)*

2.5.1. Marine Mammals

Humpback Whale

Humpback whales migrate annually from Antarctic feeding grounds to the Kimberley coast for calving during the winter. Humpback whales predominantly occur offshore in open oceanic environments. However, they are known to stopover in the lee of the offshore islands and have been observed on several occasions during the humpback southerly migration, within 5 km of the Mardie Project Marine Development Envelope, by O2M staff in 2018. The southern migration is the period when they are closest to shore at an average of 36 km although are often recorded in waters less than 10 m deep during the latter part of the migration (September to December). The Project area is a shallow embayment (i.e. generally <5m deep) and could not be considered critical habitat for any whale species.

Dugong

Dugong (Dugong dugong) are found throughout the Pilbara region, particularly close to the coast or in the lee of reef-fringed islands and often in areas where seagrass has previously been recorded. Although Dugong have been previously recorded in the nearshore waters of the Mardie coastline, the nearest known Dugong aggregations have been recorded near Cape Preston in the North and Coolgra Point in the South, generally in areas that consistently support extensive seagrass meadows (O2 Marine, 2020d).

No Dugong were observed in the waters around Mardie during over 700 hours of vessel-based observations. O2 Marine (2020d) concluded that this was most likely due to the lower value of the subtidal BCH in the area as suitable feeding or foraging habitat for Dugong. However, surveys for seagrass (and dugong) were not undertaken during peak seagrass season (October-December). Nevertheless, dugong may be present in the Project area, particularly between June – September, with calving season from August to December and management measures have taken the precautionary approach that consider impacts to this species.

Australian Humpback Dolphin

The Australian humpback dolphin was the only conservation significant species known to occur in the Project area, with records of Australian humpback dolphins (*Sousa sahulensis)* reported throughout the year at the Montebello Islands (Raudino *et al* 2018) and in the Mardie Project area. They are likely to be one of the most common dolphin species occurring in the Project area. This species together with the Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*) are likely to be the most abundant dolphin species in the Mardie Project area inside the 20 m isobath.

2.5.2. Marine Turtles

Only a small part of potential marine turtle nesting beach lies within the development envelopes, a narrow section of the beach labelled as ‘Mardie Creek East’ in Figure 92. The Pendoley (2019) survey identified only very minor nesting effort by Flatback turtles and a single hawksbill turtle, along the 15 km stretch of coastline to the east of the creek. These results indicated that the mainland beaches are not currently a regionally important rookery. The results of the temperature loggers also confirmed that mainland beaches were significantly warmer than the offshore islands, impacting the success rate of any marine turtle nests on these beaches.

With the exception of the single hawksbill nest recorded on the mainland in December (albeit past the peak of the hawksbill nesting season), turtles nested most successfully on the offshore islands; 34 – 42 % of Flatback and 36 – 50 % of hawksbill nesting attempts on the islands resulted in a nest. None of the three Flatback nesting attempts on the mainland resulted in a nest. This variation in nesting success may be related to the varying nesting habitat characteristics between the island and mainland monitoring sites. For example, the island sites featured a wide supratidal zone, a well-defined primary dune, and fine-medium grained sand size that may have facilitated the successful deposition of a clutch, whereas the mainland sites featured a narrow supratidal zone, little or no primary dune development, and medium-coarse grained sand size that may have hindered successful clutch deposition.

The main species recorded on the offshore islands was Flatback turtles, with relatively less nesting effort seen for hawksbill and green turtles at the same locations. The snapshot monitoring data from Round, Middle, and Angle Islands confirmed similar species composition and abundance at these sites. These results are consistent with turtle activity throughout the Pilbara where Flatback and Hawksbill nesting is dominant on nearshore island habitat, and Flatback turtles are the most common mainland nesting species (Pendoley et al., 2016).

Baseline artificial light results found the overhead skies at the Proposal are typically very dark and representative of pristine, natural dark skies unaffected by artificial light. The only light source visible from all mainland and offshore light monitoring sites was the Sino Iron facilities located over 30 km away on the easterly horizon. However, artificial lighting is considered to have an impact on marine turtles and will be managed using the Mardie Project Illumination Plan.

2.5.3. Elasmobranchs (Sawfish)

The Northwest Marine Region is considered a particularly important area for two sawfish species because the region and adjacent inshore coastal waters and riverine environments contain nationally and globally significant populations of sawfish species (DSEWPaC 2012). However, relatively little is known about the distribution and abundance of sawfish species in north-western Australia (Morgan 2012).

In the Pilbara, green sawfish are known to utilise the mouths of major river systems (i.e. Ashburton River) as pupping grounds and nursery areas, before juveniles migrate into adjacent creeks at approximately 3 to 6 months old, and then further offshore to mature at a length of about 3 m (Morgan 2012). Acoustic tracking of green sawfish from the Ashburton shows that the species does not travel more than 700m upstream from the mouth of the river. In the Western Pilbara they are assumed to be present in all tidal creeks. In the Project area larger systems are represented by the Robe River and Fortescue River. Green sawfish are currently known from Exmouth Gulf, Whim Creek, Beagle Bay, Pender Bay, King Sound in Western Australia. Tidal mangrove systems, river estuaries, and rivers of the King Sound provide ideal nursery habitat for juveniles <0.5m (Whitty et al, 2011 and Whitty, 2017, Elhassan 2018). Studies also indicate movement of the species away from turbid areas and low-salinity areas i.e. when rainfall flushes estuaries etc. mangrove and inshore areas used as nurseries where they spend their first few years of life and then move to deeper waters (Elhassan 2018). Pupping normally occurs in the tidal creeks between September to October.

Green sawfish are expected to be present in the creeks, mangroves and rivers of the Mardie coastline. The habitats present within the intake creek are well represented in the region with as many as a dozen smaller size creeks within 100 km.

2.5.4. Sea Snakes

The Short-nosed sea snake has not been previously recorded in the Mardie Project area. This species is typically found in coral reef habitats, which in the waters of the Project area are largely confined to the nearshore islands with fringing coral reefs and/or isolated reef patches. However, recent modelling and surveys undertaken by have found the species will utilise nearshore habitats (Udyawer et al. 2020). Therefore, the project has the potential to impact the habitat of this species and the precautionary approach has been applied for the species.

3. Dredging Program

3.1. Scope of Works

The scope of dredging elements of the Project includes:

1. Mobilisation and installation of a floating excavator and support barges;
2. Preparation of the onshore dredge material disposal area;
3. Testing sediments prior, during and post dredging
4. Dredging of the Berth Pocket and transport of dredged materials to the dredge material disposal area;
5. Dredging of the approach channel and transport of dredged materials to the dredge material disposal area;
6. Dredged materials handling and testing at the dredge material disposal area as required;
7. Pre- and post-dredge hydrographic survey(s); and
8. Demobilisation and site clearance upon completion of the Works.

3.2. Sequence of Works

The project allows for excavation works to be carried out 12 hours per day, 7 days per week, during suitable weather conditions outside of environmental windows. The planned project sequence is as follows:

1. Equipment preparation, inspection, certification prior to departing for site;
2. Preparation of all relevant detailed management plans to ensure compliance with conditions and specifications;
3. Pre-dredge hydrographic survey and land survey for the disposal area;
4. Mobilisation of all plant and equipment;
5. Site set-up, including preparation of disposal area;
6. Commence and complete dredging of access channel and berth pocket, and disposal of dredged materials;
7. Progressive hand-over hydrographic surveys for each section;
8. Final land-survey of “as-placed” dredged materials;
9. Demobilisation and site clearing.

3.3. Preliminary Construction Schedule

Under the current project schedule, dredging construction activities are planned to commence in accordance with this plan as soon as practicable once all required internal and external approvals are granted. Dredging and onshore spoil disposal is proposed to be undertaken over a period of between 10 and 18 months (weather-dependent). A preliminary project schedule is presented in **Table 4**.

Table 4. Preliminary project construction schedule

PROJECT SCHEDULE MILESTONE	ESTIMATED DURATION
Project Preliminaries	6 weeks
Mobilisation & Installation	12 weeks
Dredging and spoil disposal	60 - 80 weeks (weather and environmental window dependent)
Final land survey	2 weeks
Demobilisation and site clearance	4 weeks

3.4. Pre and Post Dredge Hydrographic Survey(s)

Each identified dredge section (separable portion) within the dredging program will have an individual pre-dredge hydrographic survey performed to determine as accurately as possible the total volume which is to be removed. Upon completion of dredging in each section, a post-dredging hydrographic survey will be carried out to determine if the specifications for that section has been met. Both surveys (pre- and post) will serve to calculate the final volumes removed.

3.5. Dredging Methodology

3.5.1. Dredging Operations

A backhoe dredge will be used to create the proposed transhipment approach channel and the berthing pocket for the project. A backhoe dredge is essentially an excavator secured to a manoeuvrable barge (**Figure 11**), where seabed material is excavated by bucket and lifted to the surface for transport to the disposal site. During dredge operations the dredge vessel will be secured to the seabed. The excavator includes a 10m^3 bucket, and it is expected that in optimal operating conditions, 50 buckets (at 80% full) will be excavated per hour (400 m^3/hr). The excavator will dump recovered material directly into a floating hopper barge, where the recovered spoil will be pumped as a slurry to the disposal location on-shore. The program is targeting a dredging rate of between 2,000 and 2,500 m^3 per day.

Pre dredging, dredging and post dredging operations will require fauna observations. The monitoring protocols and procedures have been informed by underwater acoustic modelling to determine appropriate exclusion areas around the noise-making activities (Talis, 2019). As detailed **Section 3.7** no Temporary Threshold Shift (TTS) in significant marine fauna is expected from dredging activities, only behavioural response; therefore the proposed exclusion zones are conservative and based on limiting behavioural response where possible. The monitoring and management actions required to protect marine fauna from project dredging activities are outlined in **Table 11** and **Section 7.1.4 .**

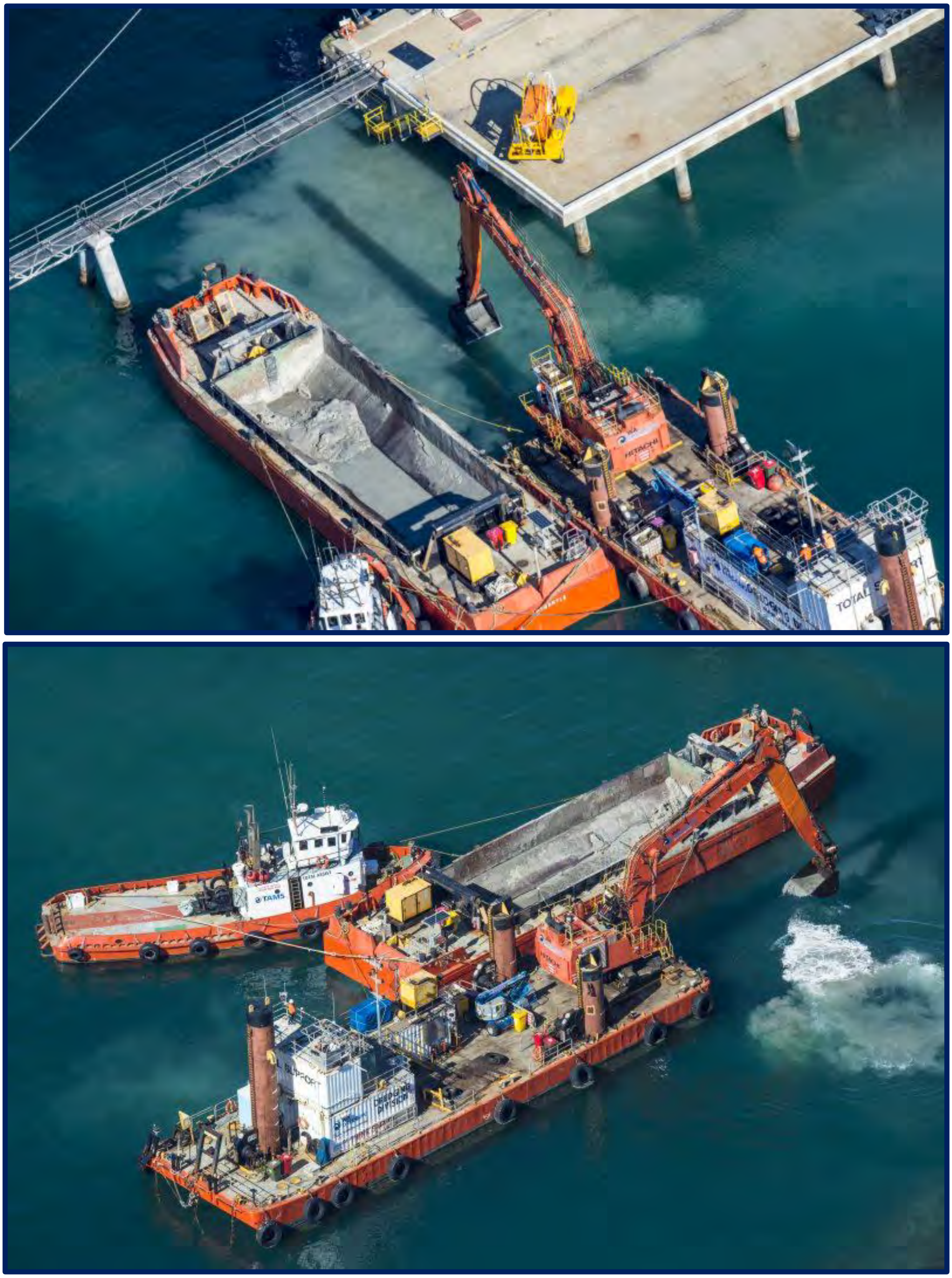

Figure 11. Example of a Backhoe Dredge proposed for Project dredging.

3.5.2. Soft Start Procedure

The soft start procedure will be implemented when re-starting all below surface operations. The soft start aims to gradually increase the level of dredging activity following a shut-down or lengthy break, with the expectation that nearby animals respond to the soft start via avoidance to the sound and are out of the disturbance/TTS threshold before the equipment is in full operation. The soft start procedure for the proposed dredging activity includes:

- Create surface splashes using excavator bucket and wait one minute;
- Slowly lower the bucket to floor and wait a further minute; and
- operate the bucket at approximately 50% rate or lower for first 5 minutes before resuming full capacity.

3.5.3. Ecological Windows

To minimise impacts to protected matters discussed in **Section 2**, including whales, dolphins, sawfish, marine turtles, dugongs and coral spawns, the following measures will be adhered to:

1. Dredging will avoid the sawfish pupping window (September – October[2]).
2. Dredging will avoid the turtle nesting, hatching and post-hatching window (August-March[3]).
3. Dredging will avoid the southern migration of Humpback Whales (September-December).
4. Dredging will not occur at any time over a period extending from 3 days before until 7 days after the predicted night of a coral mass spawning.
5. Outside these periods, dredging (excavation) will take place up to a maximum of 12 hours per day (during daylight hours), noting that disposal operations and servicing activities are not included in this restriction.

These marine fauna protection measures are in addition to those set out in Section 6.3.

3.6. Dredge Plume Modelling

Baird Australia Pty Ltd was engaged to undertake dredge plume modelling in relation to the proposed dredge scope at Mardie. The objectives of the modelling were to:

1. Determine the location, extent and duration of a potential dredge plumes;
2. Model realistic sediment plume outputs over the proposed dredge period relevant to the scale of the dredging (including potential worst-case impact scenarios) to guide appropriate management (discussed in this document); and
3. Assess the likely dredge plume impact in relation to turbidity on biota and BCH.

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[2] Further studies are scheduled over 2021/22 to refine the expected timeframe for pupping and the presence of sawfish pups in and around the dredge area, for possible inclusion in future versions of this plan and subject to approval by DWER, on advice from AWE.

[3] Further studies are scheduled over 2021/22 to refine the understanding of the potential interaction between turtle hatchlings and dredging at Mardie, for possible inclusion in future versions of this plan and subject to approval by DWER, on advice from AWE.

The modelling software used is the Delft3D model suite, an industry standard model system developed by Delft Hydraulics (now Deltares), in the Netherlands. The model consists of several modules capable of simulating the complex hydrodynamic processes in the nearshore environment and assessment of sediment plumes associated with the planned dredging activities (Baird 2020a).

The FLOW and WAVE modules were applied to recreate the environmental forces acting through the water column during the different dredge sequences, influenced by tides, wind and waves. The model utilised a combination of regional scale hydrodynamic and wave models for the north-west shelf (NWS) (Figure 12), and specific baseline data collected at Mardie by O2 Marine (O2 Marine 2020).

The dredging approach and methodology was defined by BCIM for incorporation into the dredge plume modelling process based on a backhoe dredge operating from a barge with a hopper alongside. Dredge rates adopted in the modelling process were based on a target production rate of 2,000 m^3 a day, with a sensitivity case examined based on an upper limit production rate of 2,500 m^3 a day. CMW (2019) provides a detailed geotechnical analysis of sediments within the dredge footprint, this information has informed understanding of the composition of the seabed material which will be dredged. The dredge material is very high in fine sediments (clays, silts) representing between 38% and 75% of the material by volume in sections of the channel. The required volume of dredging material was calculated through the footprint based on high resolution multibeam survey and requirements to achieve the target design depth which is -3.9m LAT in the channel and -6.7mLAT in the berth pocket.

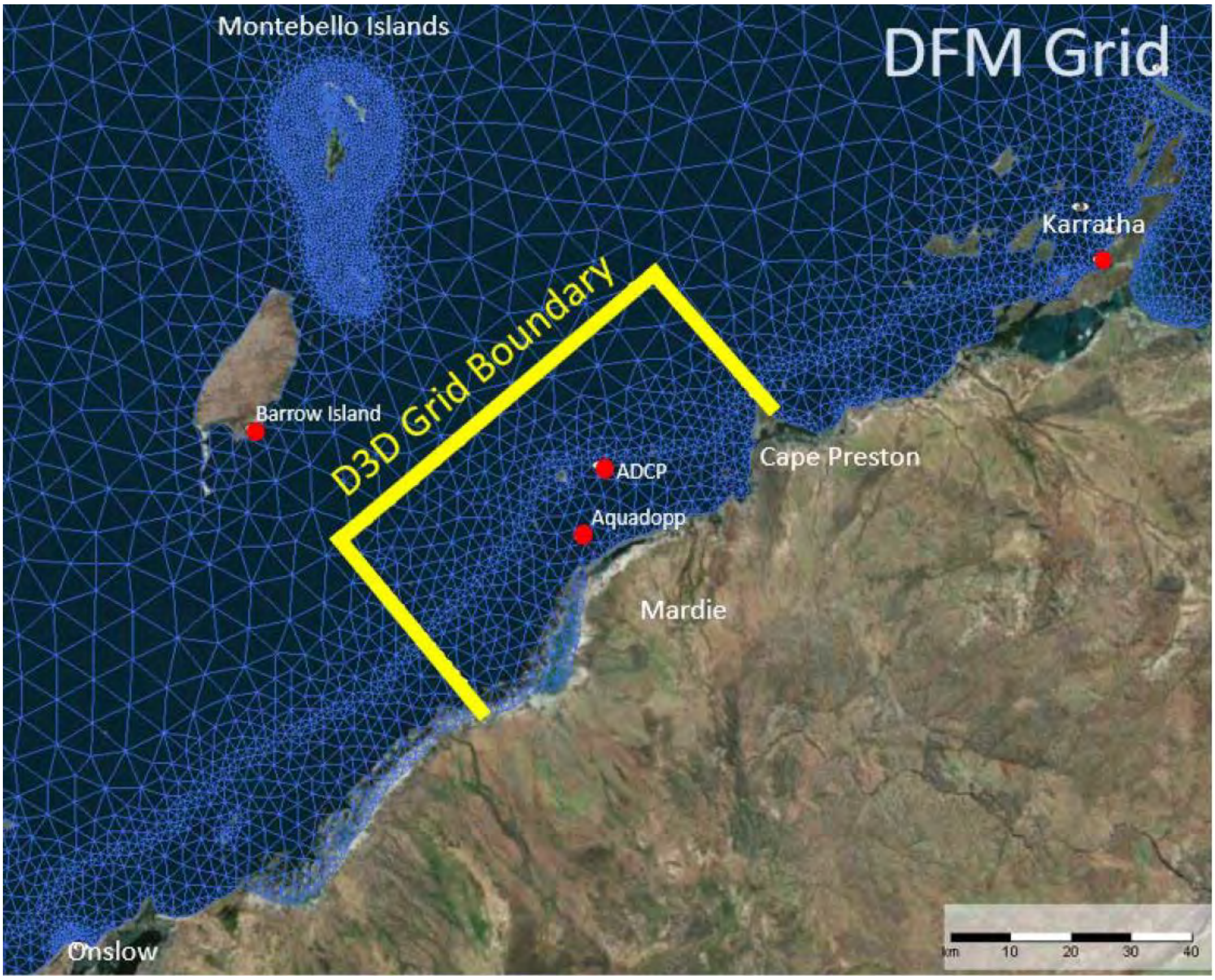

Figure 12.Area of Interest for Local Scale Model, overlain on Existing Regional Model Grid (Baird 2020b).

Sediment plumes from dredging will be generated from two principal sources: mobilisation of fine sediments at the excavator bucket with each load and overflow water from the hopper barges. These have been input to the model as:

- 4% by mass of total fine sediments (fine sand, clay and silt fractions) lost as the bucket comes up through the water column from the seabed; and
- 10% by mass of fines (< 62um) in suspension in the hopper discharging into the upper water column (conservative assumption).

The preparation of the time series inputs to the model cases were developed based on the dredging volume requirements and considering the geotechnical investigations and sediment sampling analysis of the seabed composition. The modelling is annualised (all year round), however, the worst-case modelled scenario (extent of dredge plume) is the dredge sequences in the dry season. Therefore, the worst-case scenarios of which the EPA'S environmental protection outcomes and resulting management actions are based upon are derived from the modelled sequences from the dry season. Dredge sequences (SEC1 through to SEC7) were established along the proposed dredge footprint, with the model simulating the dredge program running over two consecutive years of dry season conditions. Modelled best and worst case scenarios (and associated zones of impact) for the different dredge sequences are shown in **Figure 13**, **Figure 14** and **Figure 15.**

The dredge plume impacts are most pronounced inshore associated with dredging of large volumes of material over a comparatively small spatial area (SEC1 – 5). For the offshore sections of the channel (SEC6 & SEC7) the dredging requirements are spread out over a much larger area and the dredge plumes impacts significantly less. Additionally, the fines content is much higher inshore than offshore (up to 75% inshore compared with 38% through the offshore sections of the channel).

The Environment Protection Authority spatially based zonation scheme to describe the predicted extent, severity and duration of impacts associated with the Mardie project dredging have been determined through the processing and assessment of the dredge plume model results. Based on guidance from the WA Marine Science Institute (WAMSI) in relation to possible and probable coral mortality thresholds (Fisher et. al. 2019), the model identified zones of predicted likely best and worst-case scenarios for both the Zone of High Impact (ZoHI) and Zone of Moderate Impact (ZoMI) for all dredge sequences combined (Figure 16). It is noted that for the offshore portion of the dredging footprint (Transhipment approach channel) the boundaries of the ZoMI best and worst case are coincident.

All sediment samples collected within the dredge footprint recorded no PASS (O2 Marine, 2019a). However, baseline sediment results indicate that dredge sediments are suitable for onshore disposal. As concluded in O2 Marine 2019a (Appendix 5-1 the Sediment Quality Assessment Report), a revised site-specific EQC was recommended and a recommended EQC has been developed for the Mardie Project area (Table 18 in O2 Marine 2019a).

Sediments will be monitored throughout the pre dredging, dredging and post dredging operations for the presence of ASS and heavy CoPC, refer to Section 6.2 for further information. In the event that higher risk PASS material (i.e., material containing a high proportion of clay and silt fines) is encountered during dredge spoil placement, then this material will be well mixed with material containing predominantly calcareous materials to ensure that the natural ANC of the marine sediments is sufficient to buffer any acid generating processes of the higher risk material.

Figure 13 shows calculated dredge plume impact areas for inshore dredge sequence SEQ1 to SEQ3. Left Image: Modelled dredge plume impact ZoMI and ZoHI based on target production rate 2,000 m^3/day ('Best Case'). Right Image: Modelled dredge plume impact areas ZoMI and ZoHI based on upper limit production rate of 2,500 m^3/day ('Worst Case').

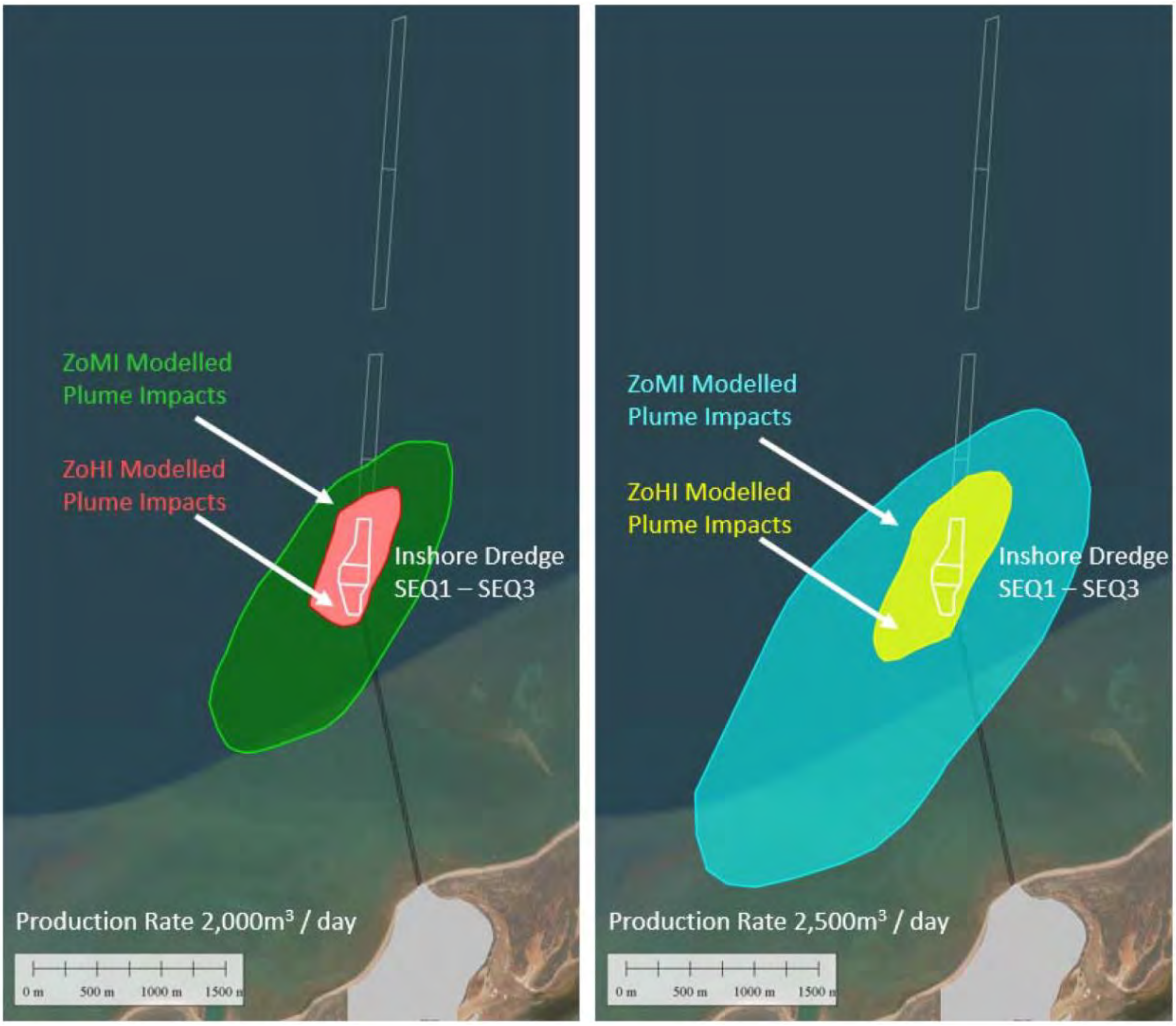

Figure 13 Calculated plume impact areas for inshore Section SEQ1 to SEQ3, best and worst case (Baird 2020b).

Figure 14 shows calculated dredge plume impact areas for inshore Section SEQ5 to SEQ6. Left Image: Modelled dredge plume impact ZoMI and ZoHI based on target production rate 2,000 m^3/day (best case). Right Image: Modelled dredge plume impact areas ZoMI and ZoHI based on upper limit production rate of 2,500 m^3/day (worst case).

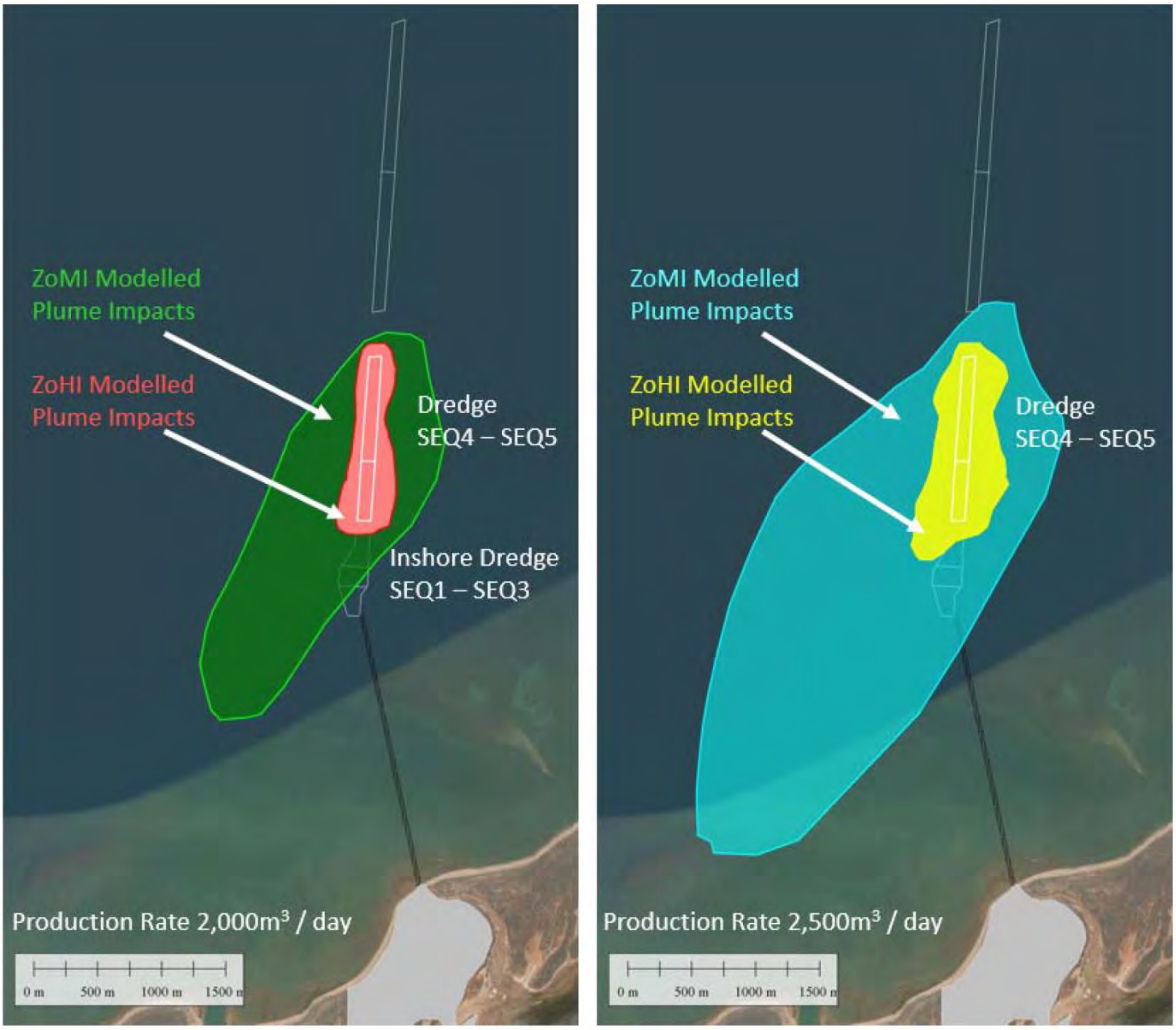

Figure 14 Calculated plume impact areas for inshore Section SEQ5 to SEQ6, best and worst case (Baird 2020b).

Figure 15 shows calculated Zones of Impact for offshore dredging in Sequence 6 and Sequence 7. Left image: Offshore dredging location. Middle Image: Modelled dredge plume impact ZoMI and ZoHI for offshore sections based on upper limit production rate (2,500 m^3/day). Right image: Adopted ZoMI and ZoHI extents are shown as polygons based on adopting a minimum distance from edge of channel. ZoHI is 25 m from channel, ZoMI is 150 m from channel. Actual modelled results are shown spatially contained within the respective bounds.

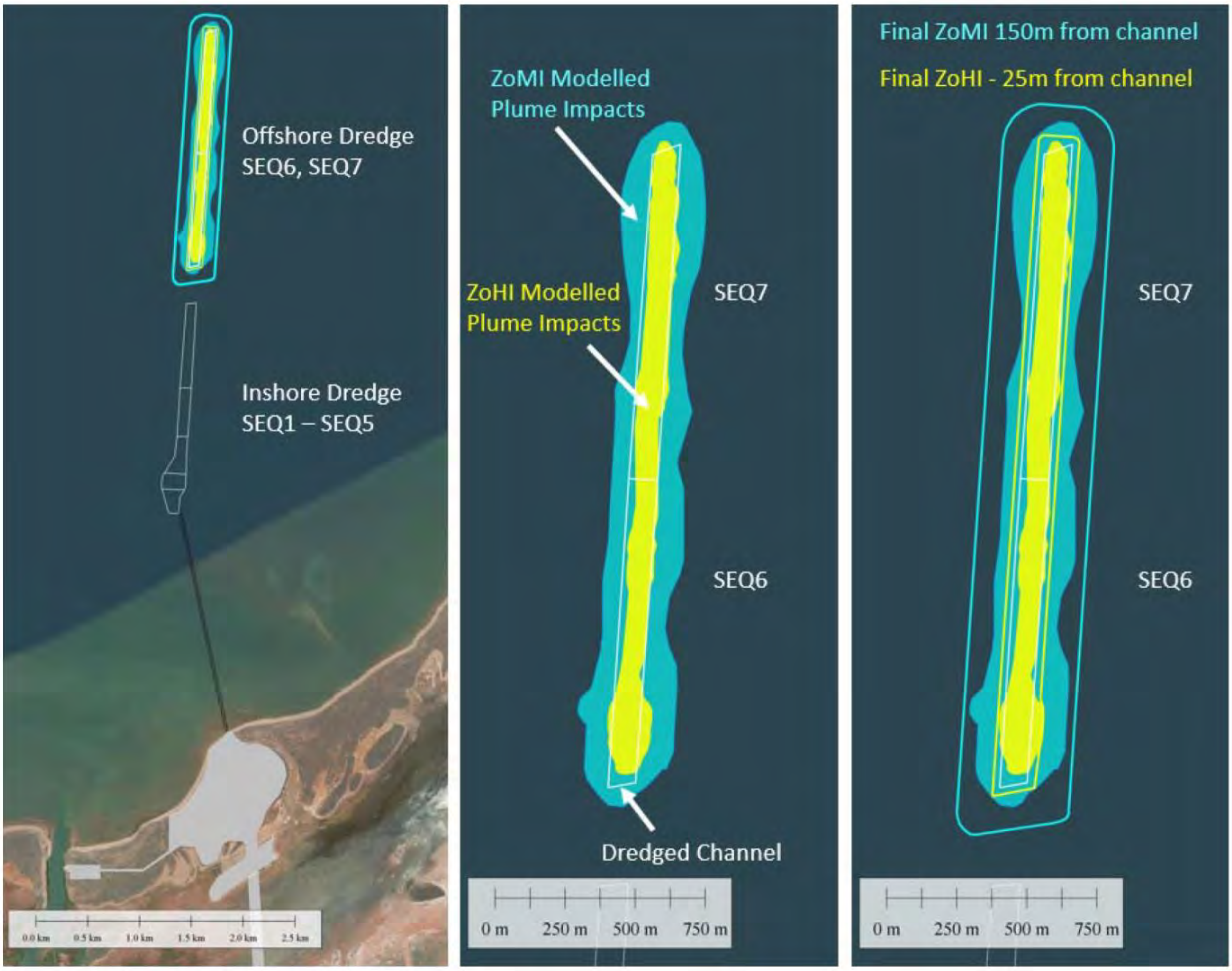

Figure 15. Calculated zones of impact for offshore dredging in Sequence 6 and Sequence 7 (Baird 2020b).

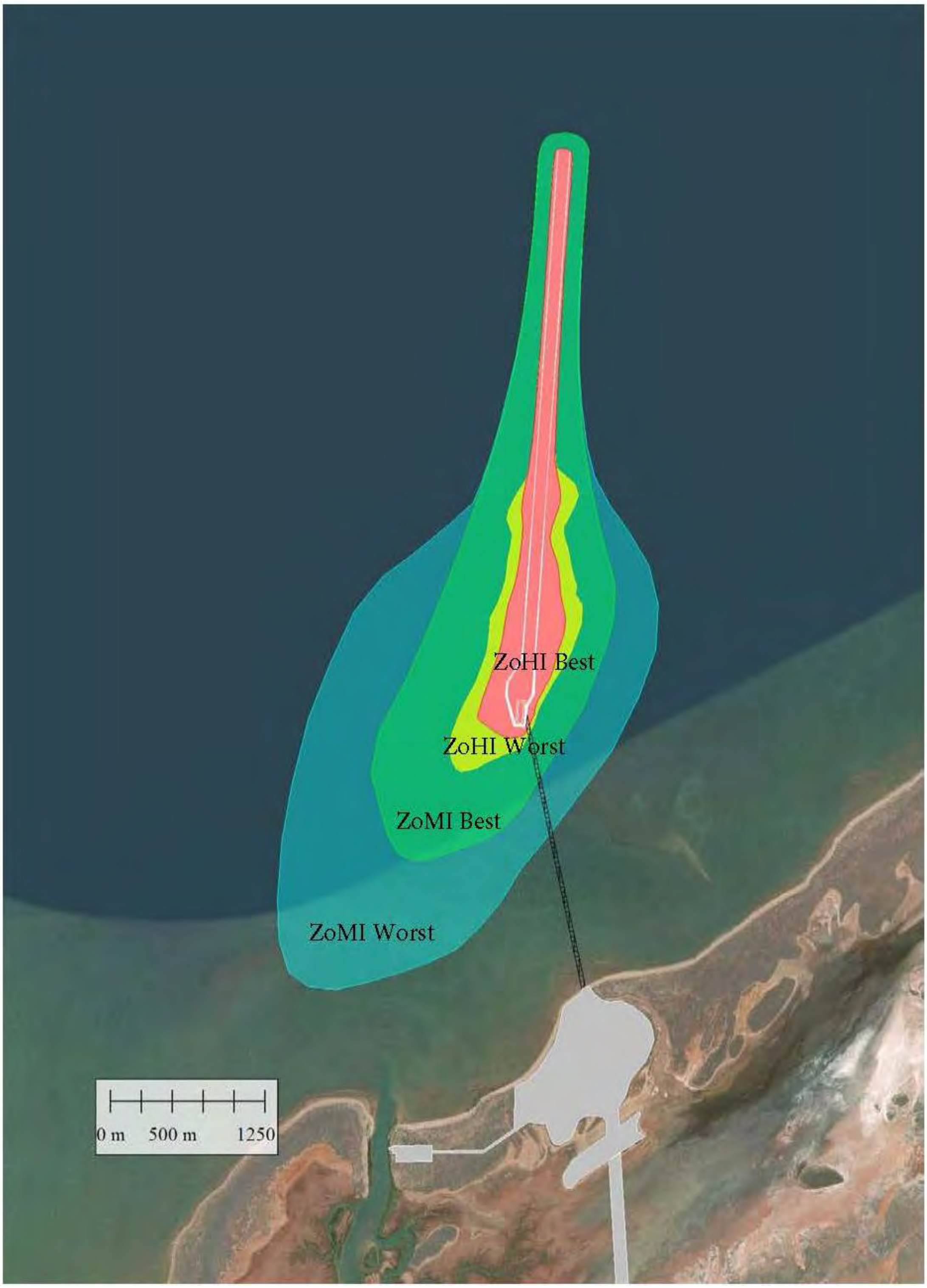

Figure 16. Calculated overall Zones of Impact (ZoMI and ZoHI) for best and worst case scenarios (Baird, 2020b)

3.7. Marine Fauna Noise Impacts

Modelling for marine fauna impacts to noise generated by the dredging operation has been undertaken (Talis 2019). The impacts have been summarised in **Table 5** below, indicating possible behavioural response for humpback whales, dugongs and Australian Humpback Dolphins. The noise management actions for marine fauna are presented in **Section 7.3** which align with the Underwater Noise Management Procedure and the EPBC Act Policy Statement 2.1.

Table 5. Dredging and barging noise impacts to marine fauna.

Marine fauna	Dredging activities	
	Possible TTS (Distances less than)	**Possible behavioral response** (Distances less than)
Humpback Whales and Dugong	No exceedance	200 m
Australian Humpback Dolphins	No exceedance	1,500 m
Marine turtles and Green Sawfish	No exceedance	No exceedance

3.8. Onshore Spoil Disposal

Dredge material will be pumped through a floating pipeline from the dredge site to the spoil disposal area (Figure 22), where the spoil will be utilised to extend and raise the port stockyard area. No dredge material will be disposed of offshore.

3.8.1. Dredge Material Management Area

The area in which the dredge material will be disposed (the Dredge Material Management Area, DMMA), is located along the southern side of the salt stockyard, where it is intended to establish the salt wash plant, stockpiles and reclaimers for the Mardie Project. The dredge material will be used to support the raising of the salt stockyard area from its current level to an even basement of 4.2 mAHD.

Bund design

The containment cells will be designed, constructed and operated to provide adequate initial storage capacity and surface area to hold the dredged materials during the filling operations and to retain the suspended solids so that the quality of discharged decant water will meet the criteria provided in Table 2.

Bund walls will be constructed with stable slopes to a minimum height of 5.0 mAHD, which will allow dredge material to consolidate to a height of 3.7 mAHD while maintaining adequate capacity for water management as well as minimum 300 mm freeboard for storm events. The walls will initially use locally competent materials but may be supplemented with suitable dredge material already within the containment cells for bund wall raises. Bund walls along the southern side of the DMMA that may encounter intertidal flows will be appropriately armoured with erosion-resistant material such as gravels and rocks overlying a geomembrane layer. Bund walls will be suitably maintained throughout the dredging phase and until covered with natural material. Those armoured bund walls that will remain throughout the project life will also be properly maintained over that period.

Management and Monitoring of PASS Risk

All sediment samples collected within the dredge footprint recorded no potential acid sulfate soils (PASS) (O2 Marine, 2019a). Therefore, baseline sediment results indicate that dredge sediments reflect natural background conditions and are suitable for onshore disposal.

To ensure the baseline assessment is appropriate, dredge materials will be tested weekly for PASS. In the unlikely event that higher risk PASS material are encountered during dredge spoil placement, the material will be well mixed with other spoil containing predominantly calcareous materials to ensure that the natural ANC of the marine sediments is sufficient to buffer any acid generating processes of the higher risk material. Monitoring of the sediments and water from the disposal area is discussed in section 7.4.

Containment and Closure

Once testing confirms the spoil material is sufficiently consolidated, the containment cells will be capped with competent material and the area used as part of the stockyard development. Remaining risks to groundwater and BCH will be assessed and addressed through the respective Groundwater and BCH Monitoring and Management Plans if considered necessary.

4. Roles and Responsibilities

Table 6. Project Roles and Responsibilities

Position	Responsibility
Proponent (as Principal)	• Overall responsibility for implementation of this DMP. • Overall responsibility for complying with all relevant legislation, standards and guidelines. • Ensures dredging activities are conducted in an environment safe for both site personnel and the public. • Reports on environmental performance for the project to relevant DMAs and to the Key Stakeholders. • Responsible for the implementation of the environmental monitoring programs and inspections. • Prepares environmental monitoring reports. • Responsible for environmental compliance reporting in accordance with Ministerial Conditions (pending). • Responsible for reporting all environmental non-compliance incidents in accordance with Ministerial Conditions (pending).
Dredging Contractor	• Prepares and implements an environmental management plan in accordance with the requirements of this DMP. • Implements the management actions of this DMP. • Ensures adequate training of all staff within its area of responsibility. • Ensures all equipment is adequately maintained and correctly operated. • Responsible for reporting all environmental incidents to Proponent Environmental Advisor within 24 hours in accordance with incident reporting procedures.
All persons involved in the project.	• Comply with the requirements of this DMP. • Comply with all legal requirements under the approvals documents and relevant Acts. • Exercise a Duty of Care to the environment at all times. • Report all environmental incidents.

5. Environmental Factors and Objectives

The key environmental factors and objectives to be managed under this DMP have been derived from the Statement of Environmental Principles, Factors and Objectives (EPA 2018), which outlines objectives aimed at protecting all environments (Themes) including: Sea, Land, Water, Air and People (**Table 7**).

Correspondence provided by the EPA, dated 13 June 2018 (case number CMS17264), outlines that of the environmental factors relevant to the proposal, three factors under theme 'Sea' are of potential significance and are relevant to the dredging scope. As a result, project specific Environmental Protection Outcomes (EPOs) and Management Targets (MT) have been derived for these three factors: Benthic Communities and Habitats; Marine Environmental Water Quality; and Marine Fauna (**Table 8**).

Table 7. Factors and Objectives (EPA 2018).

Theme	Factor	Objective
Sea	Benthic Communities and Habitats	To protect benthic communities and habitats so that biological diversity and ecological integrity are maintained.
	Coastal Processes	To maintain the geophysical processes that shape coastal morphology so that the environmental values of the coast are protected.
	Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.
	Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.
Land	Flora and Vegetation	To protect flora and vegetation so that biological diversity and ecological integrity are maintained.
	Landforms	To maintain the variety and integrity of distinctive physical landforms so that environmental values are protected.
	Subterranean Fauna	To protect subterranean fauna so that biological diversity and ecological integrity are maintained.
	Terrestrial Environmental Quality	To maintain the quality of land and soils so that environmental values are protected.
	Terrestrial Fauna	To protect terrestrial fauna so that biological diversity and ecological integrity are maintained.
Water	Hydrological Processes	To maintain the hydrological regimes of groundwater and surface water so that environmental values are protected.
	Inland Waters Environmental Quality	To maintain the quality of groundwater and surface water so that environmental values are protected.
Air	Air Quality	To maintain air quality and minimise emissions so that environmental values are protected.
People	Social Surroundings	To protect social surroundings from significant harm.
	Human Health	To protect human health from significant harm.

Table 8. Potential Environmental Impacts, Environmental Protection Outcomes and Management Targets for Mardie Project.

Environmental Factor	EPA Objective	Potential Environmental Impact Pathway	Environmental Protection Outcome (EPO)	Management Target	Management Measures
Benthic Communities and Habitats	To protect BCH so that biological diversity and ecological integrity are maintained.	• Direct loss of BCH through dredging.	• No irreversible loss of BCH outside of the worst-case ZoHI. Refer to Figure 16	• No irreversible loss of BCH outside of the best-case ZoHI. Refer to Figure 16	**Table 9**
		• Indirect impacts on BCH associated with changes to water quality (increased suspended sediment and/or sedimentation).	• No irreversible loss of BCH outside of the worst-case ZoHI. Refer to Figure 16 • No negative change from the baseline state of BCH outside of the worst-case ZoHI and ZoMI. Refer to Figure 16	• No negative change from the baseline state of BCH outside of the best-case ZoHI and ZoMI Figure 16.	
		• Indirect impacts on BCH associated with leaks or spills of hydrocarbons or chemicals.	• No irreversible loss, or serious damage to BCH outside of the worst-case ZoHI. Refer to Figure 16	• Manage vessel bunkering, chemical storage and spill response to minimise impacts to the marine environment.	
		• Indirect impact to BCH health due to Introduced Marine Pests (IMP).	• No irreversible loss, or serious damage to BCH resulting from IMP introduced through project vessels.	• Manage project vessels activities to prevent IMP impacts on the environment.	
Marine Environmental Quality	To maintain the quality of water, sediment and biota so that environmental values are protected.	• Contamination of water resulting from a vessel/hydrocarbon spill (i.e. bunkering operations).	• N/A.	• Manage vessel bunkering, chemical storage and spill response to minimise impacts to the marine environment.	**Table 10**

Environmental Factor	EPA Objective	Potential Environmental Impact Pathway	Environmental Protection Outcome (EPO)	Management Target	Management Measures
		• Disturbance of contaminants and Potential Acid Sulphate Soils (PASS) during marine construction activities (dredging). • Monitoring of the dredge materials prior to dumping, dewatering and consolidation of onshore disposal runoff into the surrounding terrestrial area, intertidal and subtidal habitats.	• Dredge spoil material will not cause harm to BCH or marine environment quality. • No dredge material will be dumped offshore.	• Assess and manage marine sediment PASS to maintain the quality the marine and land environment. • Assess and manage sediment disposal area to maintain the quality of the marine and land environment. • Minimise potential for failure of dredge transport pipeline and containment bunds.	
Marine Fauna	To protect marine fauna so that biological diversity and ecological integrity are maintained.	• Disturbance, Injury or death of marine fauna as a result of dredge operations.	• N/A.	• Manage dredge operations so no injury or death of marine fauna occurs.	**Table 11**
		• Injury or death of marine fauna due to vessel movement (strike).		• Manage vessel speed so no injury or death of marine fauna occurs as a result of vessel strike.	
		• Indirect impacts on marine fauna habitat through decreased water quality.		• Manage dredge activities to minimise turbid plumes as to not impact marine fauna habitats.	
		• Disturbance, Injury or death from contaminated water from hydrocarbon spills.		• Manage vessel bunkering, chemical storage and spill response to minimise impacts to marine fauna.	

Environmental Factor	EPA Objective	Potential Environmental Impact Pathway	Environmental Protection Outcome (EPO)	Management Target	Management Measures
		• Introduced Marine Pests (IMP) translocation from construction or operational vessels. • Noise impacts from dredging operations		• All relevant vessels to comply with Commonwealth Department of Agriculture and Water Resources – Australian Ballast Water Management Requirements. • Comply with marine noise management procedures *EPBC Act Policy Statement 2.1 – Interaction between offshore seismic exploration and whales*	

6. Management

The potential environmental impacts identified above in **Table 8**, have been assigned monitoring and management actions to measure compliance against the EPOs[4] and MT. Management measures for each environmental factor (EPA, 2018) are detailed below.

6.1. Benthic Communities and habitats

Management proposed to minimise potential impacts on the environmental factor 'Benthic Communities and Habitat' are described in **Table 9**.

Table 9. Management actions to minimise impacts on Benthic Community Habitats

Environmental Factor	Benthic Communities and Habitats
Activity	Capital Dredging and Maintenance Dredging
Potential Impacts	• Direct loss of BCH through dredging (capital and maintenance). • Indirect impacts on BCH associated with changes to water quality (increased suspended sediment and/or sedimentation). • Indirect impacts on BCH associated with leaks or spills of hydrocarbons or chemicals. • Indirect impact to BCH health due to Introduced Marine Pests (IMP).

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
No irreversible loss of BCH outside of the best-case ZoHI.	6.1	• Undertake a HAZID risk assessment with all parties to ensure potential impacts on	• Proponent / Contractor	• Minutes of HAZID	• Prior to commencement of dredging.	• N/A - Completed

[4] EPOs identified in Table 8 are not presented in the following tables as it is assumed that if the MT is achieved then the corresponding EPO will also be achieved.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
		BCH are known and understood.				
	6.2	• Utilise a satellite-based vessel monitoring system on dredge vessel to ensure no works outside the approved disturbance area.	• Contractor	• Inspection of satellite-based vessel monitoring system. • Daily dredge logs submitted to the proponent throughout construction.	• Prior to and during dredge operations. • Weekly throughout construction	• Cessation of dredging activities; and • Maintenance of tracking system.
No negative change from the baseline state of BCH outside of the best-case ZoHI and ZoMI	6.3	• Monitor dredge operations (duration, intensity, overflow rates etc) to minimise and control SSC where possible.	• Contractor	• Daily dredge logs submitted to the proponent throughout construction.	• Weekly throughout construction	• Modify or cease dredging activities if required.
	6.4	• Implement Benthic Habitat Monitoring Program (BHMP) as per **Section 7.2**	• Contractor	• BCH Assessment Report including data (photographs)	• Quarterly during baseline period (12 months) • Reactive during dredging, following level 3 management trigger. • Within 12 months following completion of dredging.	• Determine source of impact and modify dredge operations if required. • If impacts are detected, then continue monitoring on an annual basis for up to 5 years post-dredging to monitor recovery. • Where BCH has not shown evidence of recovery within the authorised ZoMI after 3 years, consider options for restoration (artificial reef, seagrass transplantation)

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
						• In the event the water quality triggers are exceeded at the outer boundary of the authorised ZoMI, the pre- and post-dredging BCH surveys will consider a variety of health measures of BCH in the areas outside the authorised ZoMI and ZoHI, which can be used to provide evidence that this EPO has or has not been met.
	6.5	• Implement the Marine Water Quality Monitoring Program (MWQMP), refer **Section 7.1**	• Contractor/ Proponent	• Telemetered Water Quality Data (i.e., DLI) • Water Quality Report	• Data recorded hourly provided daily. • Monthly	• Determine source of impact and modify dredge operations if required.
	6.6	• Undertake plume validation monitoring with Aerial Multisectoral Imagery	• Proponent	• Plume Validation Report	• At Start of Dredging. • Quarterly during dredging, and • Following a Level 2 management trigger (Table 14)	• Investigate other data sources to validate plume model (e.g., MODIS imagery).

Manage vessel bunkering, chemical storage and spill response to minimise impacts to the marine environment.	6.7	• Develop and implement project specific management procedures:
		  ◦ Chemical Storage and Handling Procedure.
		  ◦ Vessel Bunkering Procedure.
			• Contractor	• Approved Management Procedures/Plans	• Prior to commencement of work.	• Develop and implement management procedures.
						• Update procedures where necessary.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
		• Shipboard Oil Pollution Emergency Plan (SOPEP).				
	6.8	• All project vessels to maintain adequate spill response equipment on board. • All crew to be trained in emergency spill response.	• Contractor	• Pre work inspection • Monthly Inspections • Crew training logs	• Prior to commencement of works • Monthly during dredge operations • Refresh training regularly throughout project	• Source spill response equipment. • Train all vessel crew.
Manage project vessels activities to prevent IMP impacts on the environment.	6.9	• All relevant vessels should comply with Commonwealth Department of Agriculture and Water Resources – Australian Ballast Water Management Requirements, the National Biofouling Management Guidelines for commercial vessels.	• Contractor	• Vessel management procedures.	• Prior to vessel entering Australian Waters or moving from one Australian port to the project site.	• Vessels are not to mobilise to project site without approved IMP documentation.
	6.10	• All vessels that mobilise to the project site are required to complete the WA Department of Fisheries (DoF's) 'Vessel Check' risk assessment (https://vesselcheck.fish.wa.gov.au)	• Contractor	• A copy of the Vessel Check report is to be submitted to PPA for assessment along with any supporting documentation including antifoul certificates and inspection reports.	• Prior to dredge entering Australian Waters or moving from one Australian port to the project site.	• Vessel are not to mobilise to project site without approved IMP documentation.

6.2. Marine Environmental Quality

Management proposed to minimise potential impacts on the environmental factor 'Marine Environmental Quality' are described in **Table 10**.

Table 10. Management actions to minimise impacts on Marine Environmental Quality

Environmental Factor	Marine Environmental Quality
Activity	Capital Dredging and Maintenance Dredging
Potential Impacts	• Contamination of water resulting from a vessel/hydrocarbon spill (i.e., bunkering operations). • Disturbance of contaminants and Potential Acid Sulphate Soils (PASS) during marine construction activities (dredging and disposal).

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
Manage vessel bunkering, chemical storage and spill response to minimise impacts to the marine environment	7.1	• Develop and implement project specific management procedures: • Chemical Storage and Handling Procedure. • Bunkering Procedure. • 3. Shipboard Oil Pollution Emergency Plan (SOPEP).	• Contractor	• Approved Management Procedures	• Prior to commencement of work.	• Develop and implement management procedures. • Update procedures where necessary.
	7.2	• All vessel equipment to be designed and operated to prevent spills and leaks through the provision of in-built safeguards such as,	• Contractor	• Monthly Inspections • Vessel management procedure	• Monthly	• Rectify any equipment that is damaged or missing as soon as practicable. • Dredge operations not to commence prior to

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
		but not limited to, relief valves, overflow protection, and automatic and manual shut-down systems.				development and approval of vessel management procedures.
	7.3	• The proponent is to be notified immediately in the event of a hydrocarbon spill of any volume. An incident report will be submitted for each spill.	• Contractor	• Verbal communication • Incident Report	• Immediately verbal communication. • Incident report submitted within 24 hrs of incident.	• Dredge operations to cease until spill investigation is complete, and or Proponent has given authority to proceed.
Assess and manage marine sediment PASS to maintain the quality the marine and land environment.	7.4	• Undertake a sediment investigation to investigate PASS in dredge sediment. environment.	• Proponent	• Assessment included in referral support document.	• Completed	• NA - Completed
Assess and manage dredge disposal to maintain quality to marine and land environment	7.5	• Undertake sediment monitoring of dredge materials during and post operations. • Monitoring program of the deposited sediments, dewatering and consolidation phase of the materials.	• Contractor	• Sediment samples collected monthly during dredge and post dredge operations	• During dredging • Post dredging (through to consolidation and capping of spoil disposal area).	• Dredging to halt if EQC are breached until management controls are reviewed and considered adequate to the altered risk profile; increase detailed sampling of discharge and receiving water quality • PASS will be well mixed with material containing calcareous materials. • Determine source of impact and modify dredge operations if required.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
	7.6	• Implement the monitoring program for discharged decant water from spoil disposal area and receiving tidal creek (refer section 7.4).	• Proponent	• Continuous monitoring of key water quality parameters, with monthly screening of other PASS indicators and CoPC	• During dredging • Post dredging (through to consolidation and capping of spoil disposal area).	• Cease discharge and/or implement additional treatment measures.

6.3. Marine Fauna

Management proposed to minimise potential impacts on the environmental factor 'Marine Fauna' are detailed in **Section 7.3** and summarised in **Table 11**.

Table 11. Management actions to minimise impacts on Marine Fauna

Environmental Factor	Marine Fauna
Activity	Capital Dredging and Maintenance Dredging
Potential Impacts	• Disturbance, Injury or death of marine fauna as a result of dredge operations. • Injury or death of marine fauna due to vessel movement (strike). • Indirect impacts on marine fauna habitat through decreased water quality. • Disturbance, Injury or death from contaminated water from hydrocarbon spills. • Introduced Marine Pests (IMP) translocation from construction or operational vessels.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
Manage dredge operations so no injury or death of marine fauna occurs.	8.1	• Implement a soft start procedure prior to activating below surface operations.	• Contractor	• Daily dredge logs.	• Each occasion, prior to activating cutter head.	• Dredge operations not to commence unless a soft start procedure has been implemented.
	8.2	• No dredging during sawfish pupping season (September – October). • No dredging between dusk and dawn during 1 Aug – 31 Mar. • Outside this period, dredging limited to 12 hours per day. • Dredging (excavation) will not occur at any time over a period extending from 3 days before until 7 days after the predicted night of a coral mass spawning.	• Contractor	• MFO logs, • Daily dredge logs.	• For the duration of dredging.	• Investigate why dredge exclusions were not followed and apply required correction actions.
	8.3	• All project vessels are to have at least one crew member trained as a Marine Fauna Observer (MFO) on board at all times.	• Contractor	• Training certificate.	• Prior to commencement of dredging.	• Dredge operations not to commence unless at least one crew member is a trained MFO.
	8.4	• MFO logs to be complete during all dredge operations.	• Contractor	• MFO logs. • Monthly Environmental Monitoring Report. • Provide report and sighting information to DBCA and DAWE (according to EPBC Act Policy Statement 2.1).	• Daily whilst dredge operations are occurring. • Reported monthly.	• Investigate why MFO logs were not complete, and ensure adequate staff and resources are in place to fulfil requirement.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
	8.5	• Dredge operations are to cease if: ○ marine reptiles, and sawfish have been observed within 200 m and dredging activities ○ no whales have been observed within 1,500 m	• Contractor	• MFO logs, • Daily dredge logs.	• For the duration of dredging.	• Investigate why dredge operations were not ceased and apply required correction actions.
	8.6	• Report any injured or deceased marine mega fauna (whale, dugong, sawfish, turtle or dolphin) or indications of coral mass spawning on the project site to the Proponent.	• Contractor	• Verbal/written communication • Incident Report • Provide report to DWER, DBCA and DAWE	• Immediately upon observation • Within 72 hours of incident	• Investigate fauna death and apply required corrective actions and or modifications to dredge operations.
	8.7	• Noise management of marine fauna observation zones and shut down zones • Soft starts	• Contractor	• MFO logs, • Daily dredge logs.	• For the duration of dredging.	• Investigate why observation, shutdown zones and soft starts were not adopted, amend were appropriate.
Manage vessel speed so no injury or death of marine fauna occurs as a result of vessel strike.	8.6	• All dredging vessels to operate at a safe speed with a maximum speed of 8 knots to avoid interaction with marine fauna at all times within project boundaries.	• Contractor	• Vessel GPS monitoring system	• Continuous throughout vessel operations.	• Investigate why vessel was recorded in excess for the defined speed limit and amend vessel operations and activities as appropriate.
	8.7	• All project vessels are to have at least one crew member trained	• Contractor	• Training certificate.	• Prior to commencement of dredging.	• Crew to undertake MFO training

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
		as an MFO on board at all times.				
	8.8	• Report any injured or deceased marine megafauna (whale, dugong, sawfish, turtle or dolphin) on the project site to the Proponent.	• Contractor	• Verbal/written communication • Incident Report • Provide report to DWER, DBCA and DAWE	• Immediately upon observation • Within 72 hours of incident	• Investigate fauna death and apply required corrective actions and or modifications to dredge operations.
Manage dredge activities to minimise turbid plumes as to not impact marine fauna habitats.	8.9	• Implement the Marine Water Quality Monitoring Program (MWQMP), refer **Section 7.1**	• Contractor/ Proponent	• Telemetered Water Quality Data (DLI) • Water Quality Report	• Data recorded hourly provided daily. • Monthly	• Determine source of impact and modify dredge operations if required.
Manage dredge activities, including maintenance, to minimise light spill, in accordance with Project Illumination Plan	8.10	• Implement the Mardie Illumination Plan	• Contractor/ Proponent	• Routine inspections • Light monitoring at set locations	• Daily • October - March	• Address non-compliant light sources immediately • Review lighting on vessels
Manage vessel bunkering, chemical storage and spill response to minimise impacts to marine fauna	8.11	• Develop and implement project specific management procedures: ○ Chemical Storage and Handling Procedure. ○ Bunkering Procedure. ○ Shipboard Oil Pollution Emergency Plan (SOPEP).	• Contractor	• Approved Management Procedures	• Prior to commencement of work.	• Develop and implement management procedures • Update procedures where necessary.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
	8.12	• All vessel equipment to be designed and operated to prevent spills and leaks through the provision of in-built safeguards such as, but not limited to, relief valves, overflow protection, and automatic and manual shut-down systems.	• Contractor	• Vessel management procedure • Monthly Inspections	• Prior to commencing dredging. • Monthly	• Rectify any equipment that is damaged or missing as soon as practicable. • Dredge operations not to commence prior to development and approval of vessel management procedures.
	8.13	• The proponent is to be notified immediately in the event of a hydrocarbon spill of any volume. An incident report will be submitted for each spill.	• Contractor	• Verbal communication • Incident Report	• Immediately verbal communication. • Incident report submitted with 24 hrs of incident.	• Dredge operations to cease until spill investigation is complete, and or Proponent has given authority to proceed.
All relevant vessels to comply with Commonwealth Department of Agriculture and Water Resources – Australian Ballast Water Management Requirements.	8.14	• All relevant vessels should comply with Commonwealth Department of Agriculture and Water Resources – Australian Ballast Water Management Requirements, the National Biofouling Management Guidelines for commercial vessels.	• Contractor	• Vessel management procedures.	• Prior to vessel entering Australian Waters or moving from one Australian port to the project site.	• Vessels are not to mobilise to site without approved IMP documentation.
	8.15	• All vessels that mobilise to the project site are required to complete the WA DoF's 'Vessel Check' risk assessment	• Contractor	• A copy of the Vessel Check report is to be submitted to PPA for assessment along with any supporting documentation	• Prior to dredge entering Australian Waters or moving from one Australian port to the project site.	• Vessels are not to mobilise to project site without approved IMP documentation.

Management Targets	Management Actions			Environmental Performance		
	Item	Actions	Responsibility	Reporting/Evidence	Timing	Contingency
		(https://vesselcheck.fish.wa.gov.au)		including antifoul certificates and inspection reports.		

7. Environmental Monitoring

7.1. Marine Water Quality Monitoring Program

7.1.1. Monitoring Rationale

The Marine Water Quality Monitoring Program (MWQMP) is to be implemented to ensure the EPOs for Benthic Community Habitats, Marine Environmental Quality and Marine Fauna are met.

Marine dredging activities have the potential to increase suspended sediment and sedimentation in marine waters. This change in water quality has potential to indirectly impact BCH by reducing light penetration through the water column and smothering of biota due to sedimentation.

To assist the design of the MWQMP and to select suitable monitoring locations, a validated hydrodynamic model undertaken at the project area by BCIM (Baird 2020) was used to model sediment plumes generated by dredge operations within the proposed dredge footprint. A brief presentation of the model results is presented in **Section 3.6** and full report is provided in **Appendix B**.

The proposed dredge footprint consists of two key zones, the offshore (Shipping channel) and the nearshore (marine precinct, berth pocket), hereinafter referred to respectively as Zone A and Zone B (**Figure 17**).

The model result show that the dredge plume impacts are most pronounced with dredging occurring at the nearshore (Zone A), which is associated with dredging large volumes of material over a comparatively small spatial area with a high proportion of fine content in the sediment. For the offshore section of the channel (Zone B), the dredging requirements are spread out over a much larger area and the dredge plumes impacts significantly less due to sediments possessing a much high grain size and quicker settling rate (Baird 2020). Moreover, the model shows a preferential plume direction along a north-east to south-west axis, with dredge plume impacts elongated to the southwest driven by the stronger flood tides in comparison to ebb tide.

The MWQMP was developed with the assumption that dredging will be undertaken sequentially through Zone A and Zone B (i.e., two separate monitoring phases): Phase 1 monitoring will be undertaken during the dredging of Zone A and phase 2 monitoring during the dredging of Zone B.

The proposed monitoring locations have been selected based on the predicted plume distribution for Zone A and Zone B and aligned along the predicted plume direction north-east to south-west axis. The location of each site will be moved to optimise the monitoring during phase 1 and phase 2 as shown in **Figure 18** and **Figure 19**.

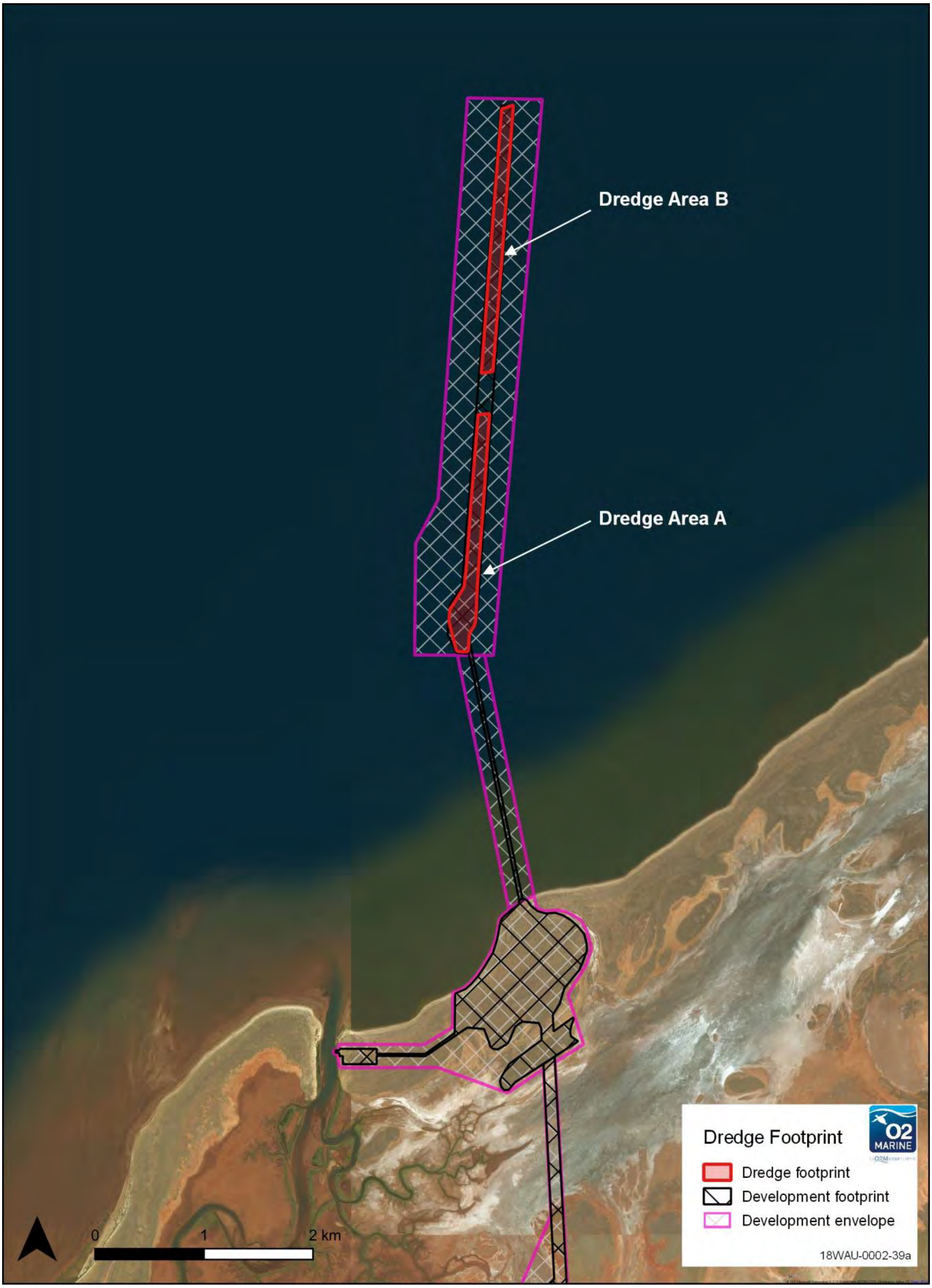

Figure 17. Proposed Dredging footprint of Dredge Zones A and B.

7.1.2. Predicted Zone of Impact and Thresholds

The model was used to develop “best-case” and “worst-case” zonation for each of the two key dredging zones (A and B), refer **Figure 18** and **Figure 19**. The best-case and worst case were derived using WAMSI threshold limit for Suspended Sediment Concentration (SSC) derived for corals (Fisher et. al. 2019) as shown in **Table 12** and **Figure 16**. The modelled SSCs were assessed against a combination of the 7, 14 and 28-day thresholds, which were applied across the model domain throughout the construction period. This resulted in the definition of likely best and worst-case Zones of High Impact (ZoHI) (irreversible loss) and Zone of Moderate Impact (ZoMI) (recoverable impact).

While the WAMSI threshold are considered appropriate to develop the modelled suspended sediment concentration to define the different zones of potential impact for dredging, these thresholds have been developed in an offshore low turbidity environment and therefore are not considered to be suitable to be used as trigger thresholds for a dredging program in an inshore environment with high turbidity levels such as the Mardie Project. Therefore, to monitor the effects of dredging activities of the project and to establish triggers for management actions, project specific threshold for SSC will be derived relative to turbidity (NTU) baseline conditions of the project area.

Prior the commencement of dredging, a site-specific calibration of SSC vs Turbidity (NTU) with an R^2 >0.5 shall be derived. The site-specific nature of calibrations has been emphasised by a number of previous studies including Fisher et. al. (2019), Sternberg et. Al. (1986,1991) and today many of the best practice guidelines for the analysis of suspended sediment state the need for site specific calibrations, see for example Judd (2012).

The calibration coefficient will be applied to the real time NTU data allowing post conversion to SSC and monitoring of established triggers.

Trigger values for monitoring will be derived in accordance with the WAMSI recommendation for coral monitoring using 12 months of baseline data which will be collected within 24 months prior the commencement of the dredging.

Table 12. Threshold Limits for Modelled Suspended Sediment Concentration used to define ZoMI and ZoHI regions through the dredge program (from Fisher et. al., 2019)

Threshold	Running Mean Period	ZoMI Threshold (>SSC)	ZoHI Threshold (>SSC)
Running Mean (SSC)	7 day	14.7 mg/l	24.5 mg/l
	14 day	11.7 mg/l	18.0 mg/l
	28 day	9.3 mg/l	13.2 mg/l

7.1.3. Telemetered In-situ Water Quality Monitoring.

Telemetered In-situ instruments will be installed to provide continuous one-hour interval water quality data throughout the dredge program. This data will be transmitted to an online data portal, to enable live updates allowing responsive monitoring and management. Each water quality sensor will be weighted to the seabed and positioned approximately 0.5m above the seabed. Each station will be tethered to a special designed telemetry marker boy (with navigation lighting) containing a battery and 3G/satellite telemetry components. Monitoring stations will be designed to be relocated as required based on dredge location.

7.1.4. Monitoring Locations & Frequency

In-situ monitoring stations will be installed either side (east and west) of dredge operations along the predicted plume southwest-northeast axe to monitor potential plume impacts on BCH. Due to the spatial extent of the dredge footprint (Zone A and Zone B) the monitoring program will be undertaken in two phases (i.e., Phase1 & 2) and the monitoring sites will be re-located in relation to the area interested by the dredging. Impact monitoring stations and corresponding reference site locations for Zone A and Zone B are identified below in **Table 13** and **Figure 18** and **Figure 19** respectively.

Monitoring stations located at the ZoMI/ZoI best case scenario boundary location will be used to monitor EPO's and MT's associated with recoverable impacts on BCH. While stations at the ZoMI/ZoI worst-case scenario location will be used to monitor EPO's and MT's associated with no negative change of BCH from baseline conditions. Note that in relation to Dredge Zone B **(Figure 17**), the ZoMI/ZoI best and worst case scenarios are spatially comparable, and therefore only monitoring of the ZoMI/ZoI worst case (no negative change) scenario is required to be monitored.

Monitoring stations will be installed 8 weeks prior to commencement of dredging and will removed no less than 30 days post dredge completion.

Table 13. Indicative Water Quality Monitoring Stations for Dredge Zone A and Zone B.

Dredge Zone	Station ID	Zone of Impact Boundary
Zone A	HBW-A	Zone of Moderate Impact - Best Case - Western Boundary - Zone A
	HWW-A	Zone of Moderate Impact - Worst Case - Western Boundary - Zone A
	HWW-A2	Zone of Moderate Impact - Worst Case - Eastern Boundary - Zone A
	ZIWN-A	Zone of Influence - Worst Case - Northern Boundary - Zone A
	ZIBE-A	Zone of Influence - Best Case - Eastern Boundary - Zone A
	ZIBW-A	Zone of Influence - Best Case - Western Boundary - Zone A
	ZIWE-A	Zone of Influence - Worst Case - Eastern Boundary - Zone A
	ZIWW-A	Zone of Influence - Worst Case - Western Boundary - Zone A
	RW-A	Reference Site
	RE-A	Reference Site
Zone B	ZIWN-B	Zone of Influence - Worst Case - Northern Boundary – Zone B
	ZIWS-B	Zone of Influence - Worst Case - Southern Boundary – Zone B
	RNW-B	Reference Site
	RNE-B	Reference Site

7.1.5. Parameters and Procedures

Each monitoring station will measure continuous turbidity (NTU) and photosynthetic active radiation (PAR) which will be introduced to derive Daily Light Integral (DLI) data throughout the dredging program. The derived coefficients from the SSC/NTU calibration will be used to convert NTU to SSC to allow comparison against WAMSI thresholds. Turbidity and DLI data will be downloaded daily using the telemetry system incorporated within the instrument buoy.

Turbidity sensors will be calibrated during regular maintenance and in accordance with manufacturer specifications to ensure accurate datasets are acquired. Water quality monitoring locations are focussed on the Eastern Side of the plume, as these habitats are dominated by coral habitats, which are the primary habitat for the benthic habitat monitoring program detailed in Section 7.2.

7.1.6. Data analysis

The likelihood of a link between dredging and water quality decline will be assessed in terms of the following factors:

- Correct instrument function and operation;
- Locations of and status of dredging activities in relation to the site(s) at the time of the exceedance;
- Hydrodynamic conditions, for example wind, tide, wave and swell state at the time of the exceedance; and
- Assessment against background conditions (reference site) and extreme weather events in the region.

Table 14. Environmental Protection Outcomes, Management Targets and Management Criteria for protection of BCH from dredging in Zone A & Zone B.

Sites	Early Warning (Level 1)	Management Target (level 2)	Environmental Protection Outcome (Level 3)
Zone of High Impact / Zone of Moderate Impact Boundary			
HBW-A	**Not Applicable**	Rolling mean DLI for either 7, 14 or 28 days to remain above the 5th percentile of seasonal baseline data for the same period. **AND** Median DLI to remain above the 5th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 7, 14 or 28 days to remain below the 95th percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 95th percentile of reference site data for the same period.	**Not Applicable**
HWW-A HWW-A2	**Not Applicable**	**Not Applicable**	Rolling mean DLI for either 7, 14 or 28 days to remain above the 5th percentile of seasonal baseline data for the same period. **AND** Median DLI to remain above the 5th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 7, 14 or 28 days to remain below the 95th percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 95th percentile of reference site data for the same period.

Sites	Early Warning (Level 1)	Management Target (level 2)	Environmental Protection Outcome (Level 3)
Zone of Moderate Impact / Zone of Influence Boundary			
ZIWN-A ZIWN-B ZIWS-B	**Not Applicable**	Rolling mean DLI for either 3, 10 or 21 days to remain above the 20th percentile of seasonal baseline data for the same period. **AND** Median daily DLI to remain above the 20th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 3, 10 or 21 days to remain below the 80th percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 80th percentile of reference site data for the same period.	Rolling mean DLI for either 7, 14 or 28 days to remain above the 20th percentile of seasonal baseline data for the same period. **AND** Median daily DLI to remain above the 20th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 7, 14 or 28 days to remain below the 80th percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 80th percentile of reference site data for the same period.
ZIBE-A ZIBW-A	**OR** Rolling mean DLI for either 3, 10 or 21 days to remain above the 20th percentile of seasonal baseline data for the same period. **AND** Median daily DLI to remain above the 20th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 3, 10 or 21 days to remain below the 80th percentile of seasonal baseline data for the same period. **AND**	Rolling mean DLI for either 7, 14 or 28 days to remain above the 20th percentile of seasonal baseline data for the same period. **AND** Median daily DLI to remain above the 20th percentile of reference site data for the same period. AND Rolling mean daily# NTU for either 7, 14 or 28 days to remain below the 80th percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 80th percentile of reference site data for the same period.	**Not Applicable**

Sites	Early Warning (Level 1)	Management Target (level 2)	Environmental Protection Outcome (Level 3)
	Median daily NTU to remain below the 80^{th} percentile of reference site data for the same period.		
ZIWE-A ZIWW-A	**Not Applicable**	**Not Applicable**	. **OR** Rolling mean DLI for either 7, 14 or 28 days to remain above the 20th percentile of seasonal baseline data for the same period. **AND** Median daily DLI to remain above the 20th percentile of reference site data for the same period. AND Rolling mean daily[#] NTU for either 7, 14 or 28 days to remain below the 80^{th} percentile of seasonal baseline data for the same period. **AND** Median daily NTU to remain below the 80^{th} percentile of reference site data for the same period

**Baseline seasonal (i.e., Summer, Winter & Transitional) percentile values (i.e. 5^{th}, 20^{th}, 80^{th} & 95^{th}) will be derived from rolling mean values for 7, 14, & 28-day periods for each season. Baseline data to be collected in the vicinity of the dredging area for at least 12-months prior to dredging.*

[#] *Rolling mean daily NTU is to be calculated once per day.*

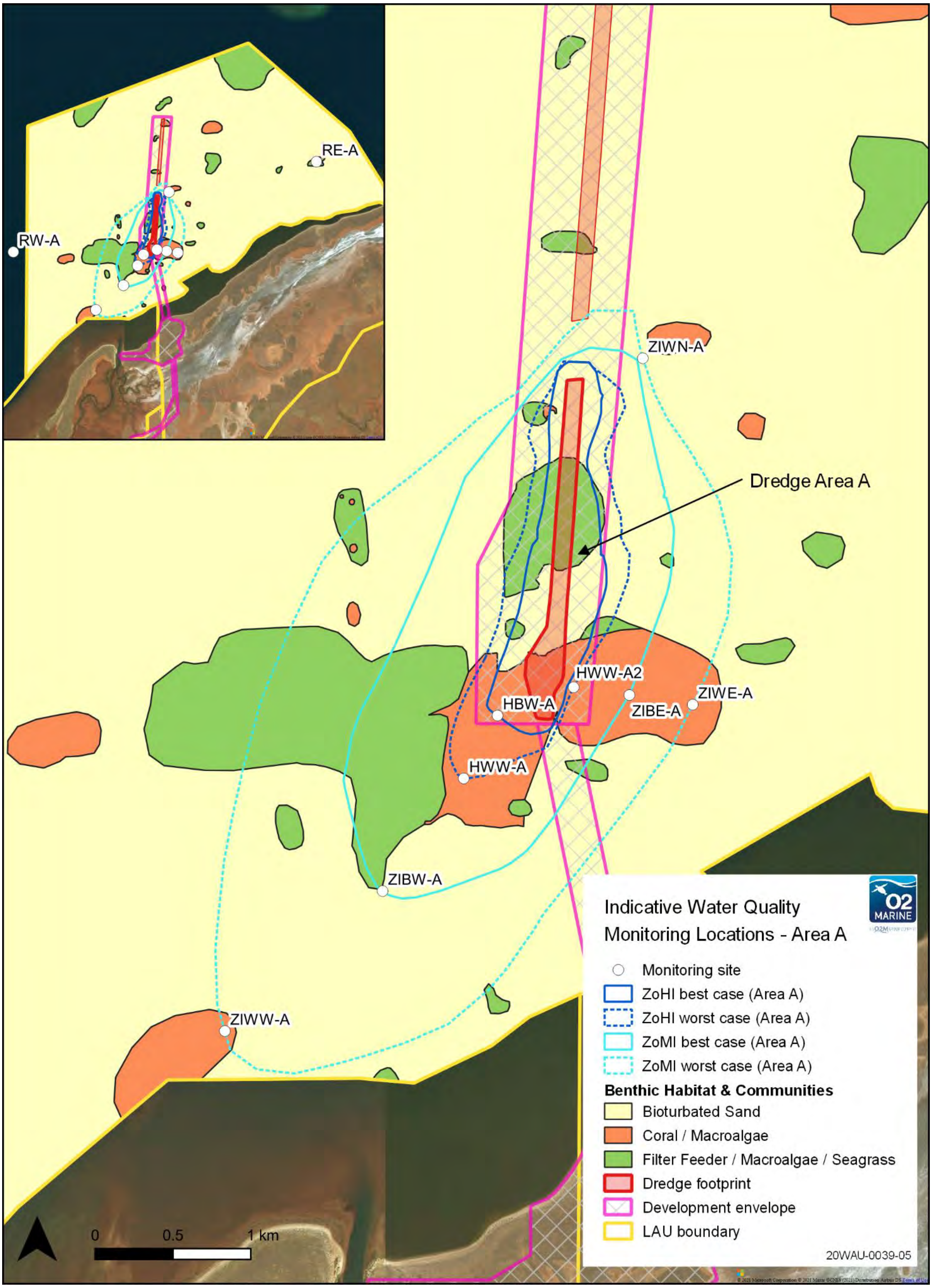

Figure 18. Dredge Zone A – Indicative Water Quality Monitoring Locations

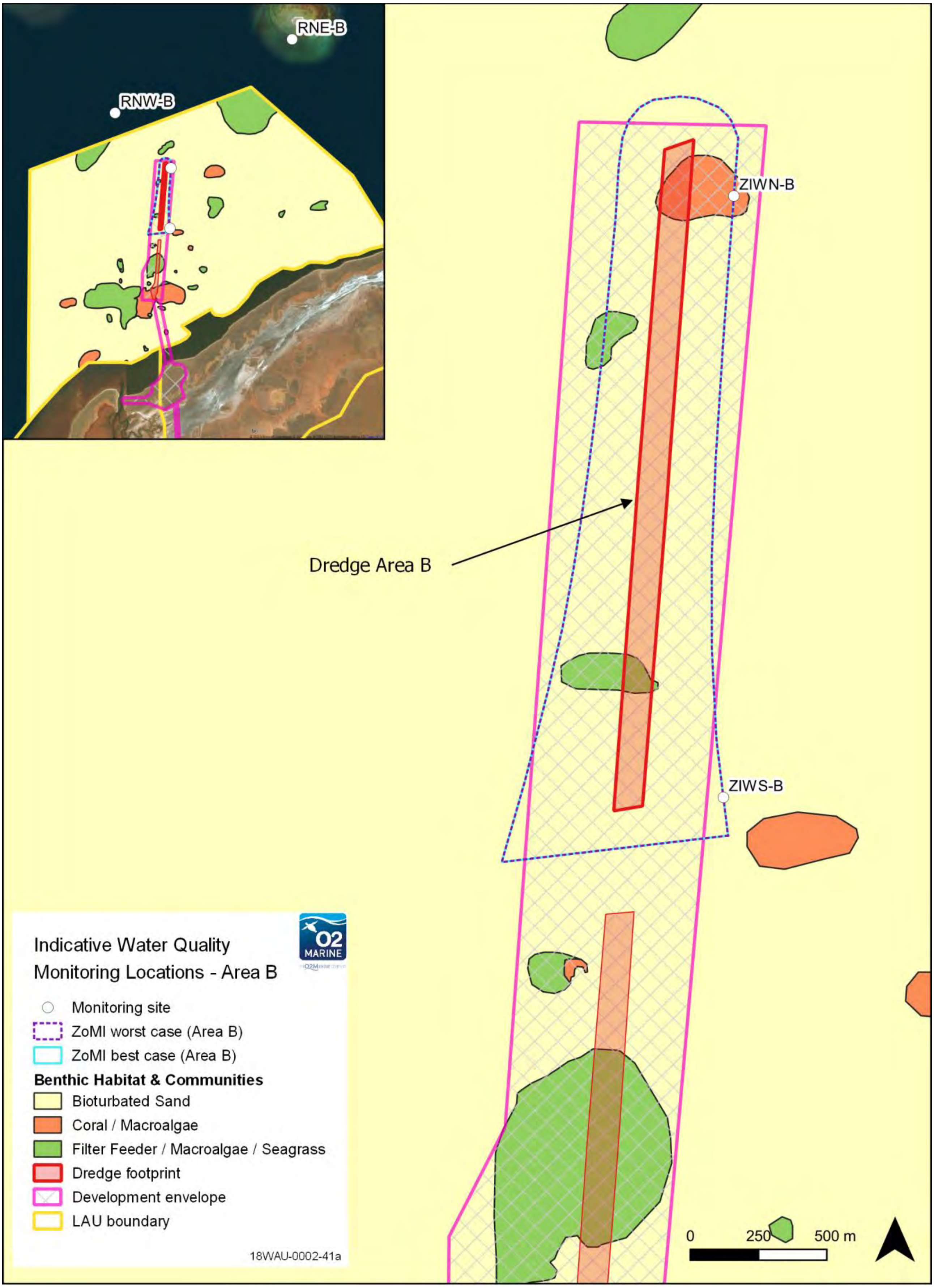

Figure 19 Dredge Zone B – Indicative Water Quality Monitoring Locations

7.1.7. Tiered Management Framework

A Tiered Management Framework (TMF) has been developed based on monitoring and reporting against the three trigger levels to ensure EPOs and MTs for protection of BCH are achieved during dredging**.** The TMF presented in (**Figure 20)** will be implemented by the Proponent/Contractor.

7.1.8. Recommencement Criteria

In the event that dredging is ceased as a result of failure to achieve the nominated water quality criteria (i.e., Management Action Level 3), then an Interim Reactive BCH Survey will be undertaken to evaluate the extent of impact (if any) to BCH arising from the dredging activities. In this instance, dredging may only recommence under the following circumstances:

- Interim reactive BCH survey confirms that no impact to BCH has occurred as a result of dredging activities;
- BCH impacts have been confirmed and reported to DWER. DWER subsequently advise that dredging in the affected area can continue under certain conditions; OR
- Dredging can be undertaken in other unaffected areas without impacting on BCH. Monitoring as per the Benthic Habitat Monitoring Program in **Section 7.2.**

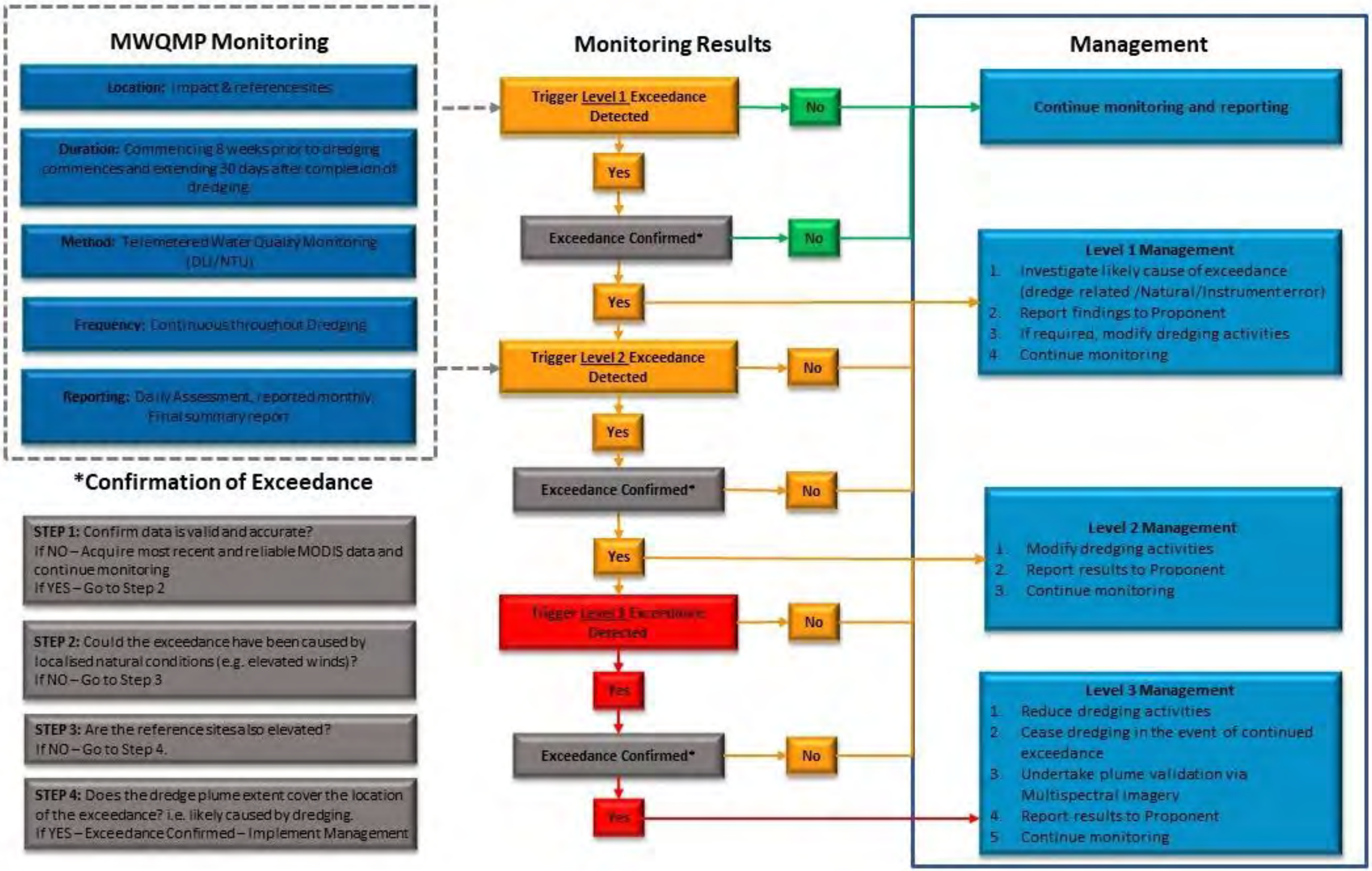

Figure 20.Tiered Management Framework for Marine Water Quality Monitoring

7.1.9. Aerial Plume Validation

Aerial multispectral imagery will be used to quantitatively assess and validate plumes models. High spatial resolution multispectral imagery validated with real-time Total Suspended Solids (TSS) samples will be captured via Unmanned Aerial Vehicle (UAV) at the start of dredging and on a quarterly basis during dredge operations. This data will allow assessment of TSS levels from dredge plumes, which are not likely to be visible via broad scale MODIS imagery due to the method of dredging and expected small scale plumes. This data will increase the accuracy of impact assessment on BCH and will help inform the predictive plume model. Multispectral imagery verification will also be implemented in the event that a Level 3 Trigger exceedance is breached (**Figure 20**). A dredge plume validation report will be prepared following each survey event.

7.2. Benthic Habitat Monitoring Program

7.2.1. Objectives

The Benthic Habitat Monitoring Program (BHMP) together with the WQMP will aim to provide an evaluation of the EPOs for BCH which are:

> Recoverable Impacts to BCH within the Zone of Moderate Impact (ZoMI); and
> No Negative Change to the Baseline State of BCH within the Zone of Influence (ZoI).

7.2.2. Monitoring Rationale

As identified in Section 2.3, coral communities are the most vulnerable (of those BCH present in the impact area) to the effects of increased SSC and the associated decline in benthic light availability. Therefore, coral health has been selected as the lead indicator for monitoring of benthic community health within the ZoMI and ZoI. Seagrass, algae, and filter feeder habitats have been selected to validate the impact at the coral sites.

Unfortunately, percent cover of BCH in the vicinity of the dredging area is generally very low (i.e., <5%) and the proportion of coral within this community is expected to be extremely low (i.e. <1%). Therefore, a standard Before After Control Impact (BACI) design focussed on overall percent cover of BCH is unlikely to achieve a statistical power to determine if any observed changes can be definitively related to dredging impacts.

Therefore, to account for the low benthic cover and to achieve a statistical power of 0.8, the BHMP will focus on monitoring of individual (tagged) coral colonies before, during and after dredging activities at the designated impact and control sites. Presence and absence surveys will also be conducted for filter feeder and seagrass habitats, with results mapped. The BHMP is designed to identify and measure changes in condition of individual colonies that are attributable to dredging activities, and which are greater than the changes occurring naturally at control sites. Additional benthic cover information will also be collected to inform multiple lines of evidence assessment.

7.2.3. Effect Size

The EPOs and associated proposed effect size for assessment of dredging-related impacts to hard coral, filter feeder, macro algae and seagrass BCH are:

> No irreversible loss of, or serious damage to, BCH outside of the ZoHI;
> Protection of at least 70% of baseline BCH (within tagged colonies) on each designated reef formation within the ZoMI; or
> No detectable reduction of net live coral cover (within tagged colonies) within the ZoI.

7.2.4. Locations

Indicative monitoring locations have been selected in areas of at least moderate benthic coral cover and these are presented in **Figure 21** and include:

- Four (4) locations within the ZoMI (ZM1, ZM2, ZM3, and ZM4) to assess recoverable impacts; and
- Two (2) locations within the ZoI and ZoMI (ZI4 and ZM5) to assist in validating potential impact; and
- Three (3) locations within the ZoI (ZI1, ZI2 and ZI3) to assess no change from baseline state.

A further three (3) reference monitoring locations are required to be determined as suitable control locations. No monitoring is proposed within the ZoHI.

7.2.5. Frequency

Baseline Surveys

BCH surveys to establish baseline condition should be undertaken quarterly and commence at least 12 months prior to commencement of dredging.

During Dredging (Reactive) Surveys

During dredging, BCH surveys are only required in the event that a level 3 management event (i.e., DLI EPO Trigger as defined in **Table 14**) is triggered.

Post-Dredging Survey

One post-dredging survey should be undertaken within 12 months following completion of dredging to evaluate status of EPOs within the ZOMI and the ZOI. Where dredging impacts are detected in areas outside of the ZOHI, then post-dredging BCH surveys will continue, on at least an annual basis, for up to 5 years, or until BCH that is impacted as a result of dredging is considered to have recovered to a pre-dredging (baseline) condition based on DWER and DAWE review of the outcomes of the monitoring program.

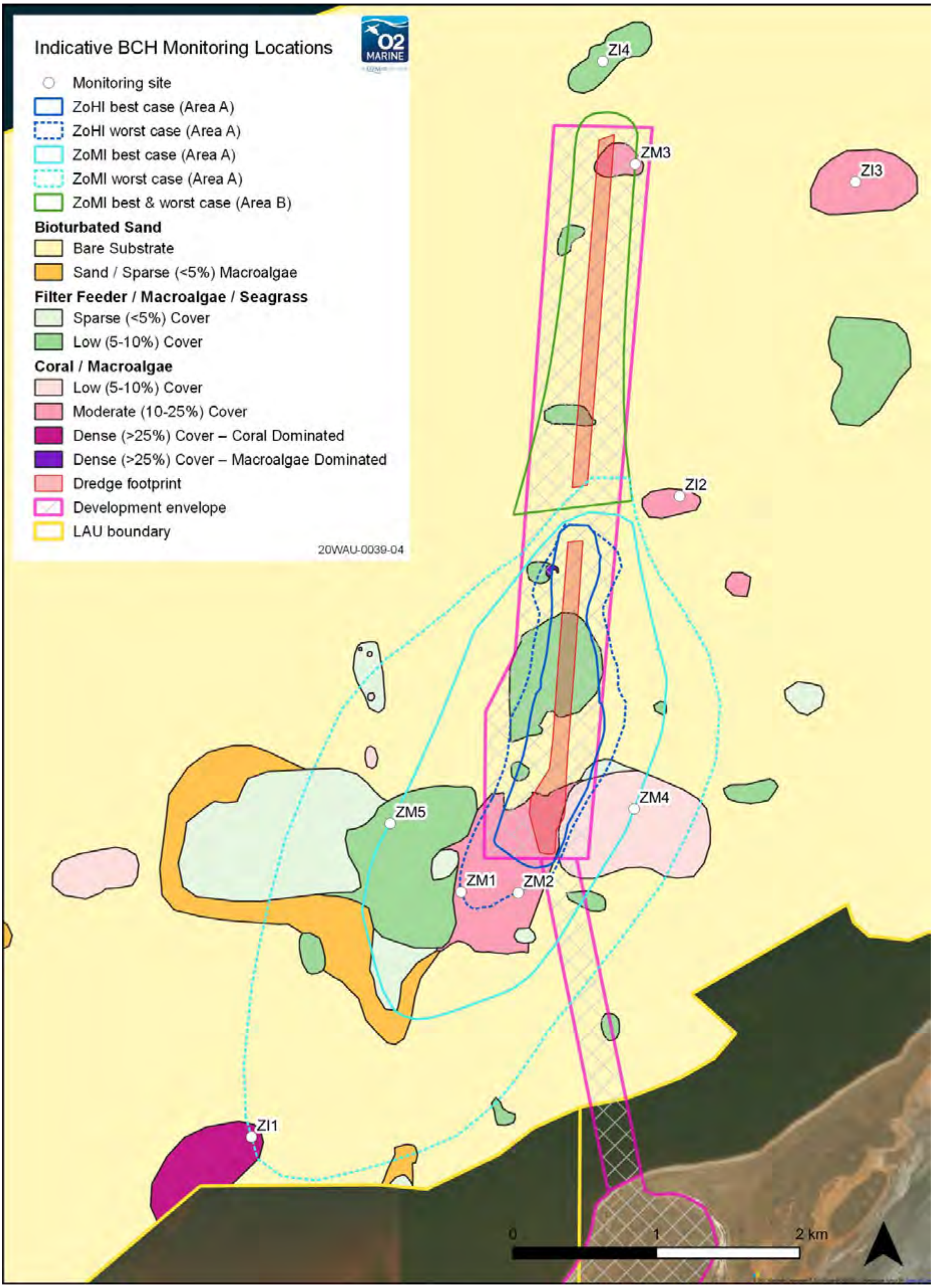

Figure 21. Indicative BCH Monitoring Locations.

7.2.6. Survey Methods

Seagrass, Algae and Filter Feeder BCH

Although seagrass was identified in the LAU, it was present only in extremely low densities (i.e., almost undetectable), making coral the primary benthic community of concern with respect to dredging impacts. The seagrass, algae and filter feeder monitoring sites (ZI4 and ZM5) will be used to validate the predicted impacts to coral habitats. Seagrass/ algae and filter feeder monitoring for community health will involve implementation of a standard before / after / control / impact (BACI) design. Diver based survey At least three (3) 50 m transects radiating in different bearings at each monitoring location, capturing still images within a 25 x 25 cm quadrat at each metre along the transects using an underwater camera. Still camera shots are taken within <1 m of the substrate. Analyse of still images using Coral Point Count software (or similar). Interrogating data to calculate simple statistics of community composition to inform assessment against baseline and reference data for benthic cover (all habitats) and shoot density (seagrass).

Individual Colonies

At each site, a total of 80 colonies will be selected, across five permanent transects (i.e., 16 colonies per transect). Colonies will be selected on the basis of an initial appraisal of condition (i.e., no obvious signs of mortality, bleaching or excessive mucous production) and targeted between the size range conducive to photography: 11-75 cm. Where larger colonies (<75 cm) are present, these colonies will be divided into smaller (0.5 m) sections along the transect for separate evaluation. Where possible, colonies will be selected from a broad range of species, representative of different family groups and morphologies at each site, including sensitive genera (e.g., *Acropora*) and less sensitive genera (e.g. *Turbinaria*).

Colonies will be selected from within 1 m either side of the permanent transects. Using the permanent transect as a reference point, the locations of colonies will be recorded using bearings and offset distances from the tape to enable re-location during subsequent surveys. Where there are limited colonies recorded, additional colonies may be added by searching the area between 1-2 m either side of the transect.

Sub-lethal indicators will be recorded for each colony *in-situ* using the classification details provided in **Table 14**. Digital photographs will be collected at distances which allow the colony to maximise the field of view on the image. A set of Coral Reference Photographs taken during the first baseline survey showing the original image of each of the corals with the location bearings and distances from the transect will be used to compare against each colony to ensure that the correct corals are assessed on each sampling occasion. Colonies will be photographed from the same orientation/perspective (from start of transect) and distance. Where an area of colony is covered in sediment, it will not be cleared away from the colonies before photographs are taken. Where macroalgae obscure a colony, the macroalgae will be moved to allow a clear photograph to be taken, unless the macroalgae are growing on or within the colony and its removal would damage either the coral or the macroalgae.

Table 15 ***In-situ*** **classification details of sub-lethal indicators to be recorded for each colony during each survey.**

Indicator	1	2	3	4	5

Partial Mortality Sediment deposition	<10%	10-30%	30-60%	60-80%	>80%
Coral colour	paling	focal bleaching	non-focal bleaching	partial bleaching	total bleaching
Mucous Production	Presence/absence				
Disease	Presence/absence & Type (i.e., White syndrome, black band, brown band, other)				
Predation/Type	Presence/absence & Type (i.e., Fish scars, Polychaetes, Tremetodes, other)				

Line Intercept Transect

A tape measure will be run over each 20 m permanent transect, then a suitably qualified coral specialist will identify and record benthic cover type and form located directly beneath the tape measure for each transect. Data will be used to calculate percentage benthic cover type across the monitoring location.

7.2.7. Data Analysis

Image Analysis

Each individual image will be analysed using coral point count with excel extensions (CPCe) to determine the extent of live coral cover for each coral colony. Sixty (60) points will be assessed per image and coral condition (i.e., live/dead) will be recorded for each point.

The sub lethal indicators recorded in the field will be evaluated to determine the metrics shown in **Table 16**. The mean of the scores from the assessment of partial mortality, coral colour and sediment deposition will be compared to the baseline record. A shift of three points on the six-point classification (including zero) will constitute an adverse change in sub-lethal coral indicators. The incidence of colonies exhibiting evidence of coral mortality, bleaching, mucous production, predation and disease will be calculated by summing the number of colonies with evidence of these effects divided by the total number of colonies. This will be expressed as a percentage reduction in coral condition from the baseline level.

Table 16 Post-processing data for the following indicators.

Indicator	Analysis Description
Partial Mortality	Total mean partial mortality[1] scores from CPCe
Colony mortality	Proportion of colonies in Category 5
Coral colour	Total mean coral colour scores[1]
Colony bleaching	Proportion of colonies in Category 4 & 5
Sediment deposition	Total mean sediment cover[1] scores
Sedimentation	Proportion of colonies in Category 5
Mucous production	Proportion of colonies with evidence of the presence of mucous
Disease	Proportion of colonies with evidence of the presence of coral disease
Acanthaster	Incidence of *Acanthaster* species along transects
Drupella	Proportion of colonies with evidence of the presence of *Drupella*
Predation	Proportion of colonies with evidence of predation

[1] All colonies included in the assessment (i.e., colonies scoring zero are included in calculating the mean)

Line Intercept Transect

The percentage of benthic species cover that directly intercept the tape measure length of each 20 m transect using the line-intercept method will be calculated into a proportion of each benthic group (i.e., 20 m equals 100%). The benthic groups used will be calculated manually in excel to determine the relative abundance, mean, standard deviation, standard error and the Shannon-Weaver diversity Index of each benthic cover type at each site. Line intercept data will not be used for EPO assessment.

7.2.8. Statistical Analysis

The process for analysis of lethal and sub-lethal data and comparison against the EPOs is shown in **Table 17**.

The first step of the analysis is a statistical paired-samples t-test of gross negative change in coral colour/bleaching, partial/colony mortality and coral cover at the impact location. This uses a null hypothesis of no difference between the impact location at time ‘x’ during dredging compared to baseline to test the one-tailed alternative hypothesis that the negative change at the impact location is significantly greater than the negative change at reference locations.

This is followed by a similar test, but of net negative change at the impact location (i.e., factoring in change in cover that occurred concurrently at reference locations). Specifically, the (one-tailed) hypothesis being tested is that difference in the negative change is greater at the impact location than at the reference locations. The appropriate statistical test is a two-(independent)-sample t-test between the average of the impact locations and the average of reference locations. This uses a null hypothesis of no difference between the impact location at time ‘x’ during dredging compared to baseline to test the one-tailed alternative hypothesis that the negative change recorded between baseline and time ‘x’ at impact locations is greater than the negative change recorded at impact locations.

The t-tests of changes within sites proposed here are equivalent to the main interaction test (before–after × control–impact) in a standard Multiple Before–After, Control–Impact (MBACI) design (Keough and Mapstone 1997; Downes et al. 2002; Quinn and Keough 2002). The only difference is that there will only ever be one measurement in the “after” (during dredging) period that is being assessed, so there is additional temporal imbalance compared to a usual MBACI design. The statistical analysis is also based on an asymmetrical design, characterised by a before versus after contrast at multiple control sites but only a single impact site. The impact sites for the tests may be grouped together to form an additional balanced statistical test where three sites represent each of the impact zones and provide greater confidence that EPOs have been achieved for the Project. Results will be compared against the results from the control reference sites to confirm impact.

A conventional Type I error rate of 0.05 will be applied across the tests. Type II error rates of statistical power will be determined during the baseline study.

Table 17 The process for evaluation of EPOs

Name	Description	Objective
Average Baseline	Calculate average measurements for each colony across each site over multiple sampling times before dredging	To determine natural levels of change before dredging

Name	Description	Objective
Gross Change	Subtract the Average Baseline from recent dredging survey for each colony/transect and average across each site	To calculate the average change from baseline to recent dredge survey at each impact and control site
Test of Gross Change	Paired-sample t-tests performed between baseline and recent dredge survey averages where negative change was recorded at impact site.	A statistically significant negative change might provide evidence supportive of a dredging-related impact.
Test of Net Change	Two-(independent)-sample t-test performed to compare negative changes between impact and control sites where negative change was recorded at impact site.	A statistically significant negative change might provide evidence supportive of a dredging-related impact.
Multiple Lines of Evidence	Detailed interrogation of all data collected using supportive univariate and multivariate analyses where Test of Net Change is exceeded	To rigorously assess whether the detected change at an affected reef was due to dredging or simply the result of natural change

Multiple Lines of Evidence

In the event that management criteria are exceeded, a series of investigations and statistical analyses will be initiated in a structured decision-making framework to rigorously assess whether the detected change at an affected reef was due to dredging or simply the result of natural change.

The first step will be an assessment of the magnitude of change (effect size and its confidence interval) in coral cover for the individual colonies between the impact and reference locations, from before dredging to the current survey period (that is, whether the difference in coral cover between the affected reef and the control reefs had increased or remained consistent since dredging). The purpose of this method is to compare the effect size during baseline with the effect size after dredging. A confidence interval approach provides important information for decision-making not gained from a test of a null hypothesis and focuses on the magnitude of change, with some measure of uncertainty. A larger mean effect size (+- CI) following dredging may provide evidence supportive of the dredge impact hypothesis.

A comparison of trends in mean coral cover through time will then be compared among the impact and reference locations. Evidence supportive of the dredge impact hypothesis would be a decline in cover at the impact location following dredging, but no corresponding decline at the reference location.

An inference assessment will then be undertaken, which includes the collation and synthesis of all available circumstantial evidence supporting or refuting the conclusion that either dredging or a natural agent of disturbance resulted in an observed decline in coral cover at the impacted location.

Multiple lines of evidence, based on causal indicators, are used to assess the impact hypothesis and may apply a variety of univariate or multivariate analysis. With lines of evidence there is a need to seek evidence not only to support the impact prediction, but evidence to rule out plausible alternative predictions, such as that the observed difference was due to natural processes (Beyers 1998; Downes et al. 2002). Potential natural or other anthropogenic causes of impact within the Project area may include thermal bleaching from warm water temperatures, natural mortality, pollution, predation, cyclonic events, salinity change and anthropogenic causes for elevated turbidity (e.g. ship propeller disturbance, maintenance dredging). Potential natural and anthropogenic causes not related to the dredging activities will be monitored and noted during routine surveys as part of the MQMP, and in some cases during the reactive monitoring program. A reactive monitoring program will be activated when there is a potential for a decline in BCH occurring, such as a spill, cyclone, or bleaching event, triggered.

A number of factors are relevant to the likelihood and level of severity of an impact occurring, including existing stress levels, age, size and health status of colonies, associated biota and adaptations to localised conditions. Differences in the physical characteristics between reference and impact locations and how this could affect the scale of effect observed between the corals should also be considered. The data will be compiled to provide a weight of evidence as to whether or not dredging activities were reasonably considered to cause or contribute to the impact.

It is predicted that for the project during the assessment: 35 ha (cleared) and 133 ha (recoverable) of filter feeder / microalgae / seagrass habitat and 10 ha (cleared) and 103 ha (recoverable) of coral / macroalgae habitat. To verify this, continuation of the post-dredging surveys on an annual basis (Maximum of five years) as required to identify evidence of BCH recovery within the authorised ZoMI. Where BCH has not shown evidence of recovery within the authorised ZoMI after 3 years, consider options for translocation, artificial reef, seagrass transplantation and/or restoration. In the event the water quality triggers are exceeded at the outer boundary of the authorised ZoMI, the pre- and post-dredging BCH surveys will consider a variety of health measures of BCH in the areas outside the authorised ZoMI and ZoHI, which can be used to provide evidence that this EPO has or has not been met.

7.2.9. Reporting

Baseline Report

The Baseline Report will be prepared following the final quarterly baseline survey be completed prior to commence of dredging. The results of the baseline surveys will be summarised and assessed with the intention to characterise natural background changes in the condition of coral communities in the areas likely to be affected by capital dredging and in the reference locations.

The report is proposed to also include a summary of the weather and marine water quality conditions (i.e., benthic light availability and turbidity), which will be recorded during the pre-dredge period (Refer **Section 7.1**). This information will be used to develop understanding of how the condition of coral communities in the areas likely to be affected by capital dredging and control locations are influenced by natural processes.

Reactive Survey Reports (If Required)

In the event that level 3 management criteria are triggered, a reactive survey investigation will be immediately (i.e., within 72 hours) undertaken. The investigation will consider relevant field observations, comparison of reference sites, water quality and sediment deposition data collected, dredge operations and metocean conditions to delineate impacts detected from natural causes or other anthropogenic sources as part of a multiple lines of assessment approach. Each reactive survey report will include:

- A summary of data collected during the survey;
- Comparison of coral community condition with baseline and against reference locations;
- Multiple lines of evidence assessment (including the outcomes from the Marine Environmental Quality Monitoring & Management Plan);

> Evaluation of whether coral EPOs been achieved or not; and
> Recommendations for additional investigations / management / monitoring if required.

Reactive survey reports should be submitted to DWER together with any required compliance investigation reports for review and recommendations of the next steps for dredging operations.

Post-Dredging Report

The post-dredging report will be prepared following completion of each annual post-dredging survey. The Post-dredging report will include:

> A summary of data collected during the survey;
> Comparison of coral community condition with baseline and against reference locations;
> Multiple lines of evidence assessment (including the outcomes from the Marine Environmental Quality Monitoring & Management Plan);
> Evaluation of whether coral EPOs been achieved or not;
> Evaluation of the effectiveness of the BHMP and WQMP; and
> Recommendations for additional investigations / management / monitoring if required.

7.3. Marine Fauna Monitoring

7.3.1. Protocols and Procedures

The monitoring protocols and procedures have been informed by underwater acoustic modelling to determine appropriate exclusion areas around the noise-making activities (Talis, 2019). As detailed **Section 3.7** no TTS is expected from dredging activities, only behavioural response, therefore the proposed exclusion zones are conservative and based on limiting behavioural response where possible.

The monitoring and management actions required to protect marine fauna from project dredging activities are outlined in **Table 11** and below:

- No dredging (underwater excavation) between dusk and dawn during 1 Aug – 31 Mar.
- Slow-start for operations applies at all times.
- A suitably trained Marine Fauna Observer must maintain a watch for cetaceans (i.e., whales and dolphins), marine reptiles and sawfish during dredge vessel transit. If any of these organisms are sighted within 300 m of the dredging vessels the maximum vessel speed must be limited to 6 kn, and the observation recorded. A speed limit of 12 kn applies at all other times.
- Dredging activities must not commence until a suitably trained Marine Fauna Observer has verified that no cetaceans, marine reptiles, and sawfish have been observed within 300 m of dredging activities and no whales have been observed within 1,500 m during the 30-minute period immediately prior to the commencement of dredging.
- A suitably trained Marine Fauna Observer must monitor a 1,500 m radius around the dredging activities continuously during these works to identify if there are any cetaceans, marine reptiles, and sawfish.

- If a suitably trained Marine Fauna Observer observes a marine turtle or sawfish within 300 m or a whale within 500 m of dredging these activities must be suspended within 2 minutes of the sighting or as soon as safely possible.
- Dredging activities that have been suspended must not recommence until the sighted marine turtle or sawfish have moved beyond 300 m, or the sighted whale has moved beyond 1,500 m of the work site of their own accord, or the marine turtle or sawfish has not been seen within 300 m, or the cetaceans within 500 m of the work site for a period of at least 30 minutes.
- Dredging activities that have been suspended for more than 15 minutes must recommence with soft start-up procedures.
- During periods of low visibility (where a distance out to 1,500 m cannot be clearly viewed), dredging may be undertaken, provided that all other limitations are met and that during the preceding 24-hour period:
    - there have not been 3 or more marine fauna shutdowns; and
    - a 2-hour period of continuous observation was undertaken in good visibility (to a distance of 1,500 m) and no cetaceans, marine reptiles and sawfish were sighted.
- Monitor and log the occurrence of sick, injured and dead turtles within the development envelope.

It is vital to ensure the protection of marine fauna for the duration of the project. The frequency and location of the observer are paramount to ensure the safety of the marine fauna, with the continuity of the project depending on their response to potential interactions with marine fauna.

7.3.2. Frequency

Marine fauna observations shall be undertaken for the duration of dredging activities.

7.3.3. Location

Appropriate monitoring locations shall be selected by the Marine Fauna Observer prior to the commencement of any dredging activities, to ensure an unobstructed view of the exclusion zones identified in **Section 3.7**

7.3.4. Responsibility

Contractor and Marine Fauna Observer.

7.3.5. Response

A log detailing marine fauna sightings and activities will be maintained on all vessels.

Any incidents that relate to marine fauna injury or mortality will be documented and reported to DoT. DoT will report all incidents of injury or mortality to the Department for Biodiversity, Conservation and Attractions and Department of Agriculture, Water and the Environment within 48 hours.

7.4. Spoil Disposal Monitoring

7.4.1. Spoil monitoring

Representative samples of dredge spoil material will be collected on a weekly basis and analysed for physical properties (particle size distribution), PASS indicators (pH, EC, pH_{FOX}, Chromium reducible sulfur suite), metals (Al, Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Sb, V and Zn) and key nutrients (TN, TIN, TP, FRP). Due to the absence of anthropogenic contaminants as identified in baseline sediment sampling (O2 Marine 2019b), there is no requirement to monitor for organic CoPC.

Environmental Quality Criteria for Mardie Sediments

O2 Marine (2019b) derived site-specific environmental quality criteria (EQC) for metals and nutrients in sediment for the Mardie Project area in accordance with DEC (2006) and EPA (2016) and are presented in Table 18.

Table 18: Environmental quality criteria (EQC) for metals and organic nutrients in whole sediment at the Mardie Project area

Analyte	Level of Ecological Protection (LEP)			
	Max	High	Moderate	Low
Units	mg/kg	mg/kg	mg/kg	mg/kg
Aluminium	10,620	17,750	17,750	26,625
Antimony	0.5	2	2	25
Arsenic	30	36	36	54
Cadmium	0.1	1.5	1.5	10
Chromium	44.5	80	80	370
Cobalt	11.8	20.4	20.4	30.6
Copper	13.5	65	65	270
Iron	42,320	73,700	73,700	110,550
Manganese	415	565	565	847
Mercury	<0.01	0.15	0.15	1
Nickel	22.3	35.8	35.8	52
Silver	0.1	1	1	3.7
Vanadium	59	104	104	157
Zinc	27.4	200	200	410
Total Nitrogen	392	660	660	990
Total Phosphorus	383	635	635	952
Nitrite+Nitrate	0.2	0.2	0.2	0.3
Reactive Phosphorus	0.2	0.4	0.4	0.6

7.4.2. Discharge Water Quality Monitoring and Management

Water quality monitoring will be conducted to ensure that the integrity and functions of the receiving environment (intertidal creeks) will not be impacted by the discharge of decant water. The proposed monitoring schedule is outlined as per the following table (Table 19).

Table 19: Proposed DMMA monitoring schedule

Aspect	Site Names	Monitoring Schedule
Discharge water quality	Discharge point	Continuous (half-hourly) for turbidity, pH (telemetered) Weekly for TTA Monthly for Dissolved Metals
Receiving water quality	Tidal Creek and Reference Creek	Continuous (half-hourly) for turbidity, pH, EC (telemetered) Weekly for TTA Monthly for Dissolved Metals

Water quality monitoring at the receiving sites will commence at least 3 months prior to the commencement of operations within the DMMA.

Environmental Protection Outcomes, Management Targets and Trigger Levels

The Environmental Protection Outcomes (EPOs), Management Targets (MTs) and trigger levels to be applied for protection of the receiving environment and management of acidification during tail water discharge from the DMMA are presented in Table 20. Water quality monitoring locations are shown in Figure 22.

Table 20: Proposed Environmental Protection Outcomes, Management Targets and Trigger Levels for protection of marine environmental quality and intertidal BCH from potential tail water discharge impacts

Monitoring Location: DMMA discharge point		Monitoring Location: Receiving tidal creek	
Located at the tail water discharge location within the DMMA, prior to discharge		Located in the nearest tidal creek approx. 500m from the discharge point	
Early warning: High Level of Ecological Protection	Trigger Level 1	Management Target: High Level of Ecological Protection#	Trigger Level 2
	Physico-chemical Turbidity: Median* <80th percentile of reference pH: >6.5 TTA: <40 mg/L		Physico-chemical Turbidity: Median* <80th percentile of reference pH: Median >20th percentile and <80th percentile of reference TTA: Median <80th percentile of reference
	Contaminants Dissolved metals: 99% Species Protection Level (SPL)		Contaminants Dissolved metals: 99% Species Protection Level (SPL)

*Median calculated based on a rolling 14-day period

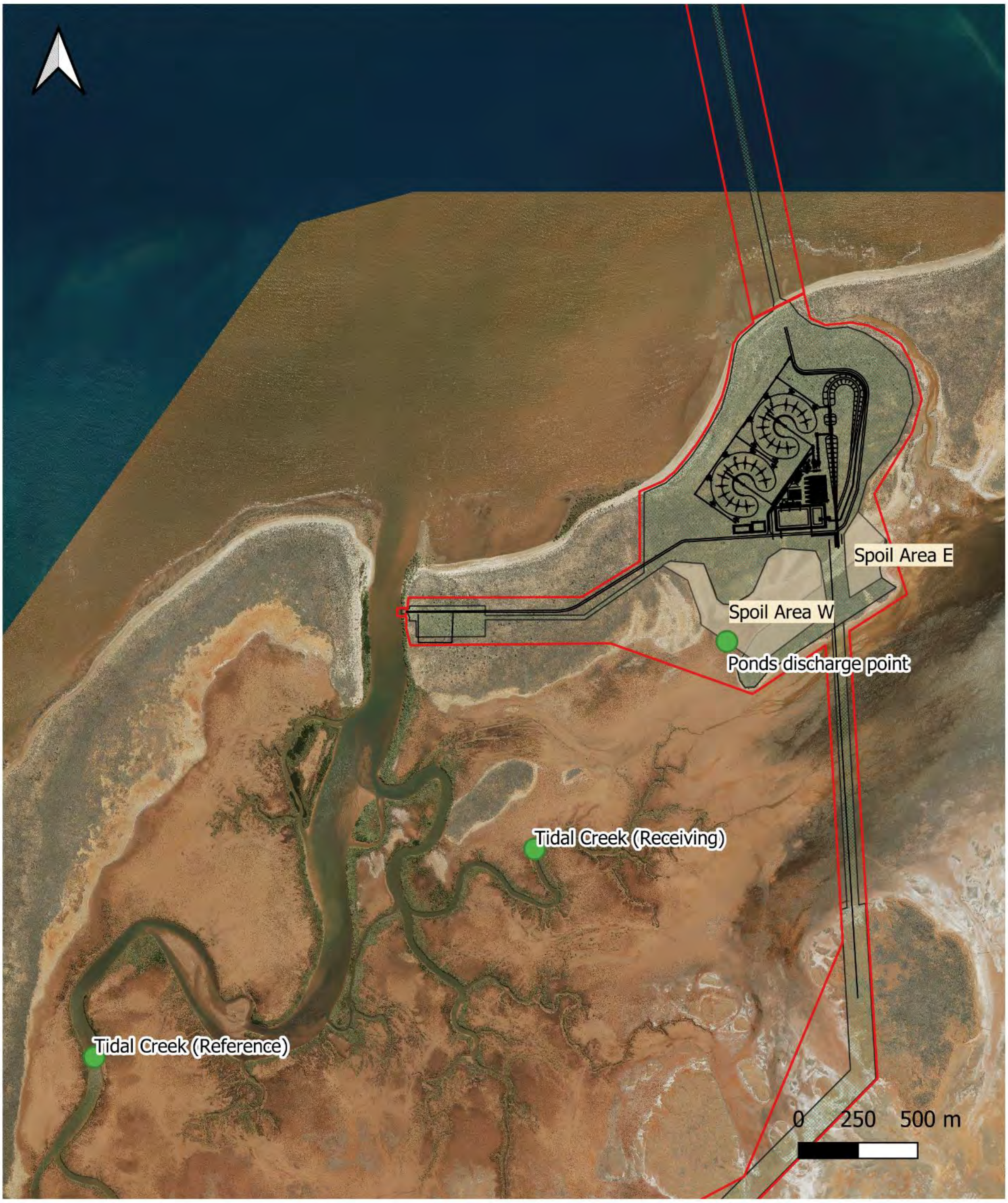

Figure 22: Onshore spoil disposal areas and water quality monitoring locations

8. Reporting

8.1. Compliance Reporting

Compliance reporting will be conducted and distributed in accordance with the requirements of the Ministerial Statement, as identified in the Mardie Project Compliance Assessment Plan.

8.2. Additional Reporting

A summary of the additional reports that are expected to inform compliance reporting commitments (Section 8.1) are listed in **Table 21**.

Table 21. Reporting Requirements throughout Dredging Scope.

Name of Report	Content	Timeframe	Responsibility	Recipient
Baseline Benthic Community Habitat Survey Report	Results and discussion of pre-dredge benthic habitat surveys. Recommendations for any amendments to the monitoring program.	Prior to commencement of dredging.	Proponent	DWER, DAWE
Reactive Benthic Habitat Survey Report	Results and discussion of reactive survey. Evaluation of monitoring results against EPO.	Immediately following water quality EPO breach.	Proponent	DWER, DAWE
Post Dredging Benthic Community Habitat Survey Report	Results and discussion of post-dredge benthic habitat survey. Describe BCH status and any further management required.	Within 12 months following completion of dredging.	Proponent	DWER, DAWE
Marine Water Quality Monitoring Report	Summary of monthly telemetered water quality data. Discuss any management actions implemented during period.	Monthly	Proponent	Internal
Dredge commencement Plume Verification Report	Results of plume verification with multispectral camera at commencement of dredging.	Within first month of dredging	Proponent	DWER, DAWE
Quarterly Plume Verification Report	Results of quarterly aerial plume verification with multispectral camera.	Quarterly following dredge commencement	Proponent	DWER, DAWE
Reactive Plume Verification Report	Results of reactive aerial plume verification with multispectral camera. Following a level 2 management target exceedance.	Two weeks following level 2 management target exceedance	Proponent	DWER, DAWE
Final Marine Water Quality Monitoring Report	Summary of all water quality data collected over the construction period. Discussing trends, exceedances and implemented management actions.		Proponent	DWER, DAWE
Marine Fauna Observer Logs	Logs continuous monitoring for Marine Fauna during dredge	Daily during dredge operations	Contractor	Proponent

Name of Report	Content	Timeframe	Responsibility	Recipient
	operations. Outlines necessary management actions where required.			DWER , DAWE
IMP Risk Assessment	Department of Primary Industries and Regional Development (DPIRD) 'Vessel check risk assessment', copy of Vessel Check report, supporting documentation including antifoul certificates and inspection reports. Statement from lead inspector on marine pest status of the vessel.	Within 72 hours of inspection.	Contractor	DPIRD
Vessel Quarantine Report	Checklist of vessel components checked during vessel inspection. Statement from lead inspector.	Within 14 days of inspection or risk assessment.	Contractor	DRIRD

9. References

ANZG 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

Baird (2020a). Mardie Project *Hydrodynamic Model Report*, 12979.101.R1.Rev1. Prepared for BCIM February 2020.

Baird (2020b). *Mardie Project Dredge Plume Modelling Report*. 12979.101.R4.RevB. Prepared for BCIM March 2020.

Beyers, D.W. 1998. *Causal inference in environmental impact studies*. Journal of the North American. Benthological Society 17: 367–373.

DEC (2006). *Background quality of the marine sediments of the Pilbara coast*. Department of Environment and Conservation, Marine Technical Report Series, No. MTR 1.

Downes, B.J., Barmuta, L.A., Fairweather, P.G., Faith, D.P., Keough, M.J., Lake, P.S., Mapstone, B.D. and Quinn, G.P. 2002. *Monitoring Ecological Impacts: Concepts and practice in flowing waters*. Cambridge University Press, Cambridge, UK.

Environmental Protection Authority (2018). *Statement of Environmental Principles, Factors and Objectives*, EPA, Western Australia.

Fisher R, Jones R, Bessell-Browne P, (2019). *Effects of dredging and dredging related activities on water quality: Impacts on coral mortality and threshold development* Report of Theme 4 - Project 4.9, prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia, 94 pp.

Jones R, Fisher R, Bessell-Brown P, Negri A, Duckworth A (2019) *Theme 4 | Synthesis Report: Defining thresholds and indicators of coral response to dredging-related pressures*. Western Australian Marine Science Institution (WAMSI). Perth, Western Australia pp. 36.

MScience (2009) Wheatstone LNG Development: Baseline Water Quality Assessment Report. Report to URS Australia Pty Ltd, November 2009.

O2 Marine (2019a). *Mardie project – Sediment Sampling and Analysis Plan Results*. Prepared for Mardie Minerals Pty Ltd. Report Number R190033.

O2 Marine (2019b). *Mardie Project – Subtidal Benthic Communities and Habitat Baseline Assessment*. Prepared for Mardie Minerals Pty Ltd. Report Number R190045.

O2 Marine (2020a). *Mardie Project – Marine Water Quality*. Prepared for Mardie Minerals Pty Ltd. Report Number R190056.

O2 Marine (2020b). *Mardie Project Marine Fauna Review*. Report Prepared for Mardie Minerals Pty Ltd.

Pearce, A. F.; Buchan, S.; Chiffings, T.; D'Adamo, N.; Fandry, C. B.; Fearns, P. R. C. S.; Mills, D. J.; Phillips, R. C.; Simpson, C. A review of the oceanography of the Dampier Archipelago, Western Australia. In: Wells, F. E.; Walker, D. I.; Jones, D. S. Editors, editor/s. (2003) The Marine flora and fauna of Dampier, Western Australia: proceedings of the Eleventh International Marine Biological

Workshop; 24 July-11 Aug. 2000; Dampier, Western Australia. Perth, W.A.: Western Australian Museum; 2003. 13-50.

Pendoley (2019). Mardie Slat Project: Marine Turtle Monitoring Program 2018/19. Prepared for BCI Minerals Ltd. Report Number: RP-59001

Sudmeyer, R (2016) 'Climate in the Pilbara', Bulletin 4873, Department of Agriculture and Food, Western Australia, Perth

Udyawer, V., Somaweera, R., Nitschke, C., d'Anastasi, B., Sanders, K., Webber, B.L., Hourston, M. and Heupel, M.R. (2020) Prioritising search effort to locate previously unknown populations of endangered marine reptiles. *Global Ecology and Conservation* 22: e01013.

Appendix A Example Marine Fauna Observation Log

MFO LOG

1. Every day requires at least one entry. Either a sighting or an entry to note 'no sightings'.
2. All cells require information when logging a marine fauna sighting.
3. Species – if species is known state species, otherwise state type of marine fauna.
4. Direction of animal to source – record using cardinal points (N, NE etc)
5. Codes for mitigation response: **SD** = shutdown, **SL** = slow dredge operations **SH** = shift dredger or **NR** = no response required.

Date	MFO Name	Time of sighting	Vessel position (lat/long)	Species	Total no. of animals	Adults	Calf	Distance to source (m)	Direction of animal from source	Mitigation response	Lost production time
03/08/18	John Smith	09:12	21.64 S 115.11 E	Dugong	1	1	0	30	NW	SL	9:12 – 9:22 10 minutes
04/08/18	John Smith - No sightings										

Appendix B Dredge Plume Modelling Report – Mardie Project